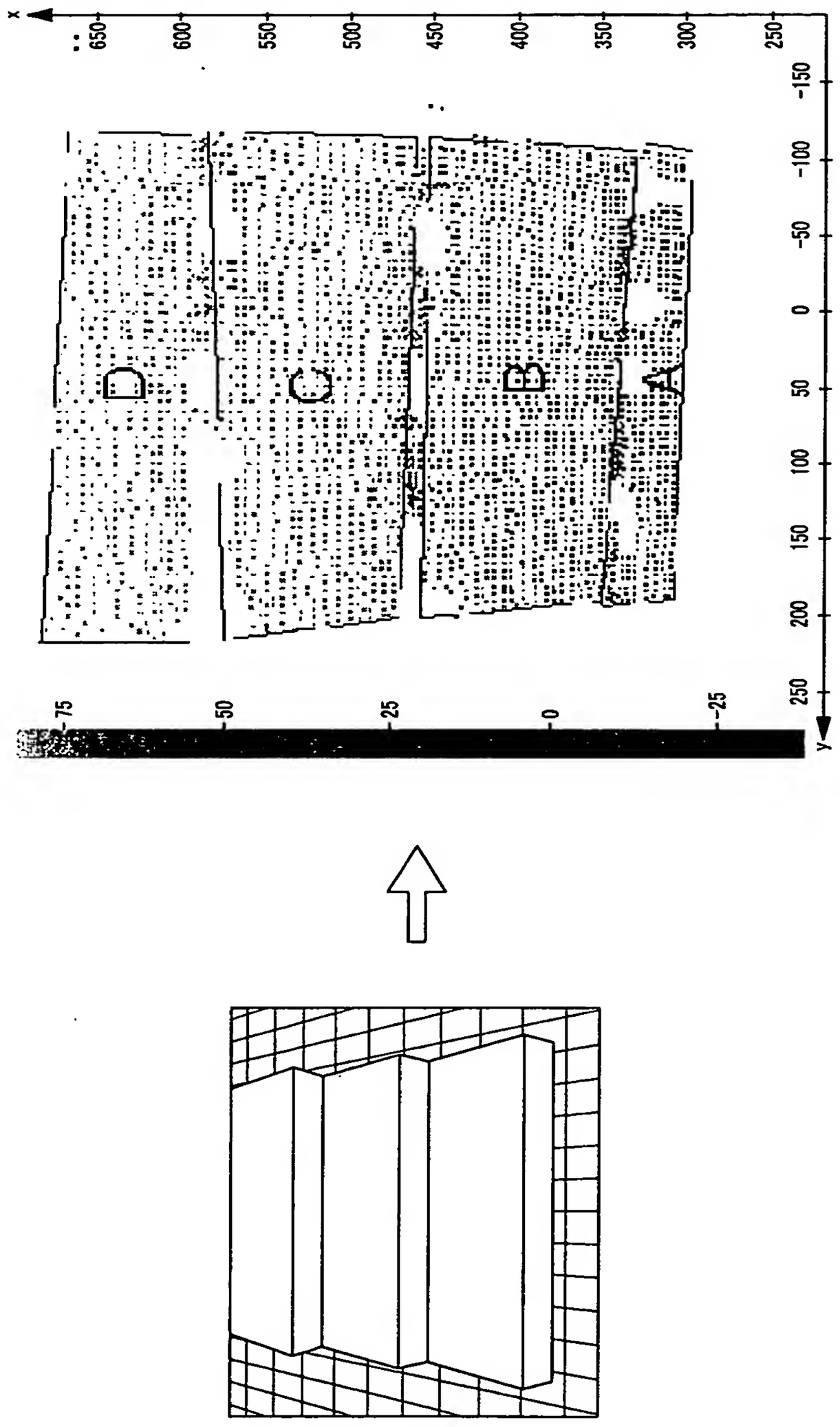


FIG.1

BEST AVAILABLE COPY

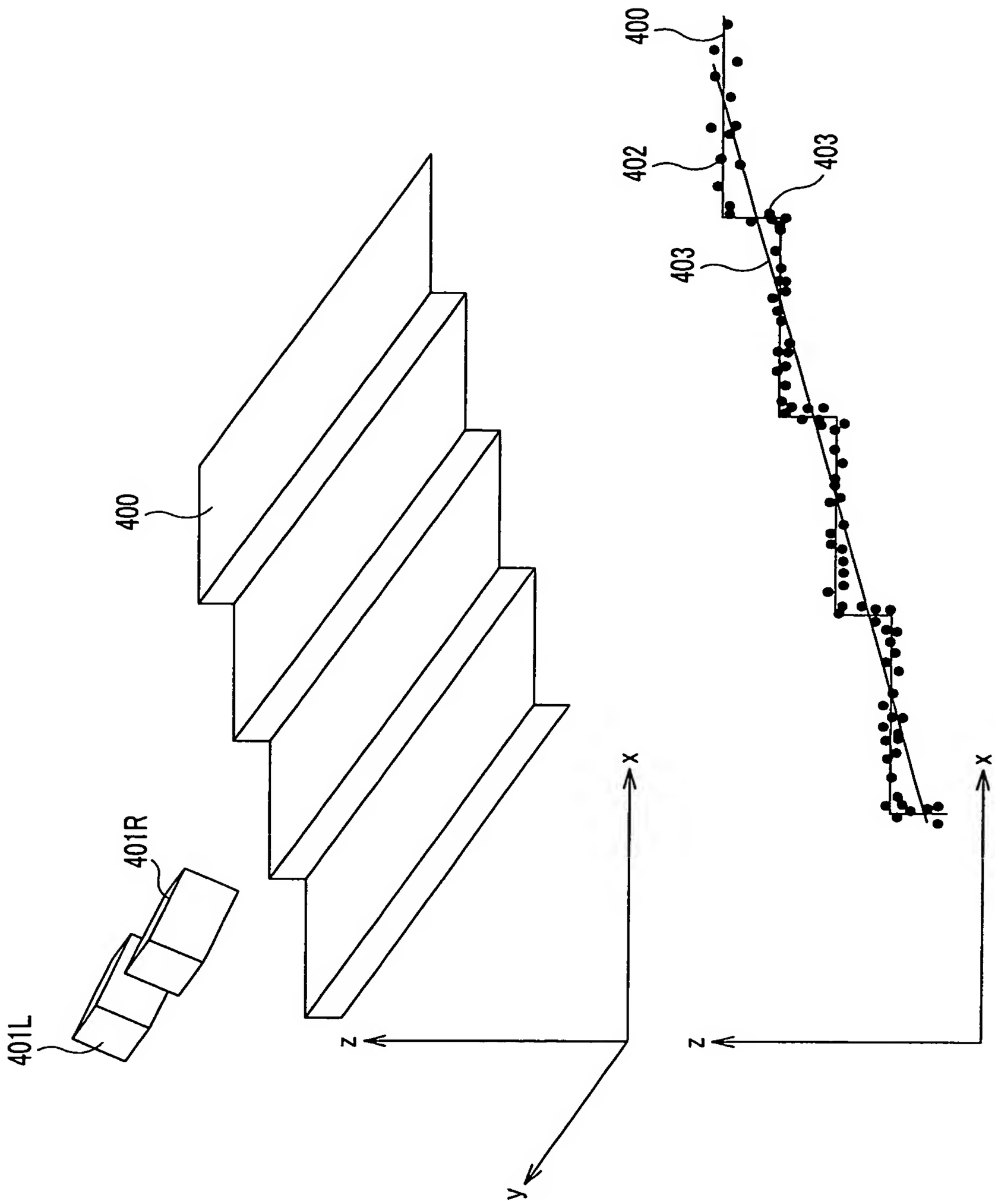


FIG.2

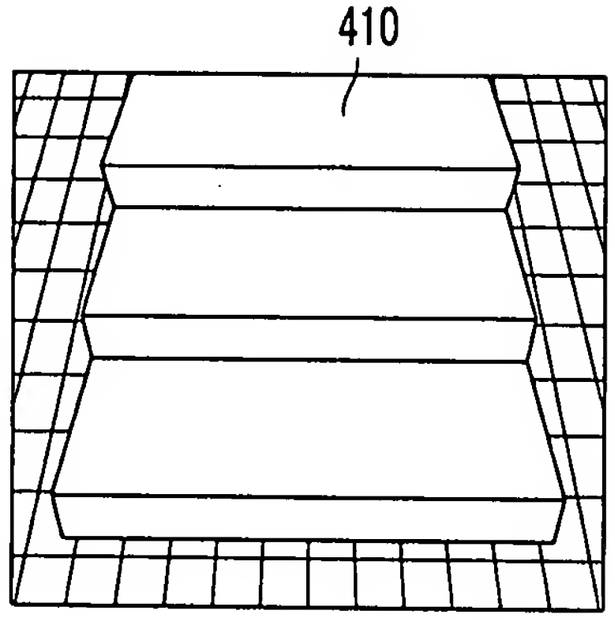


FIG.3A

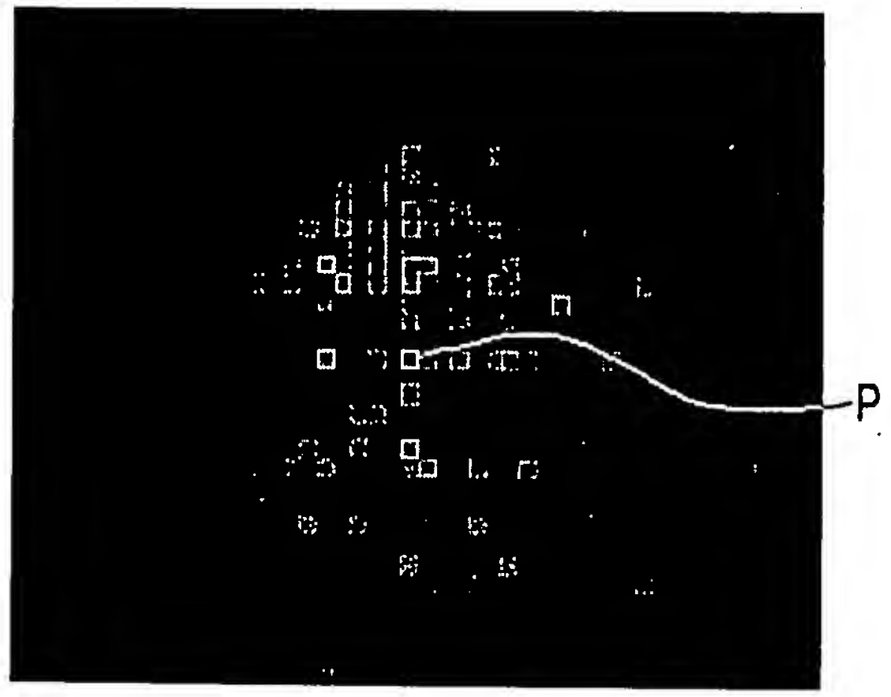


FIG.3C

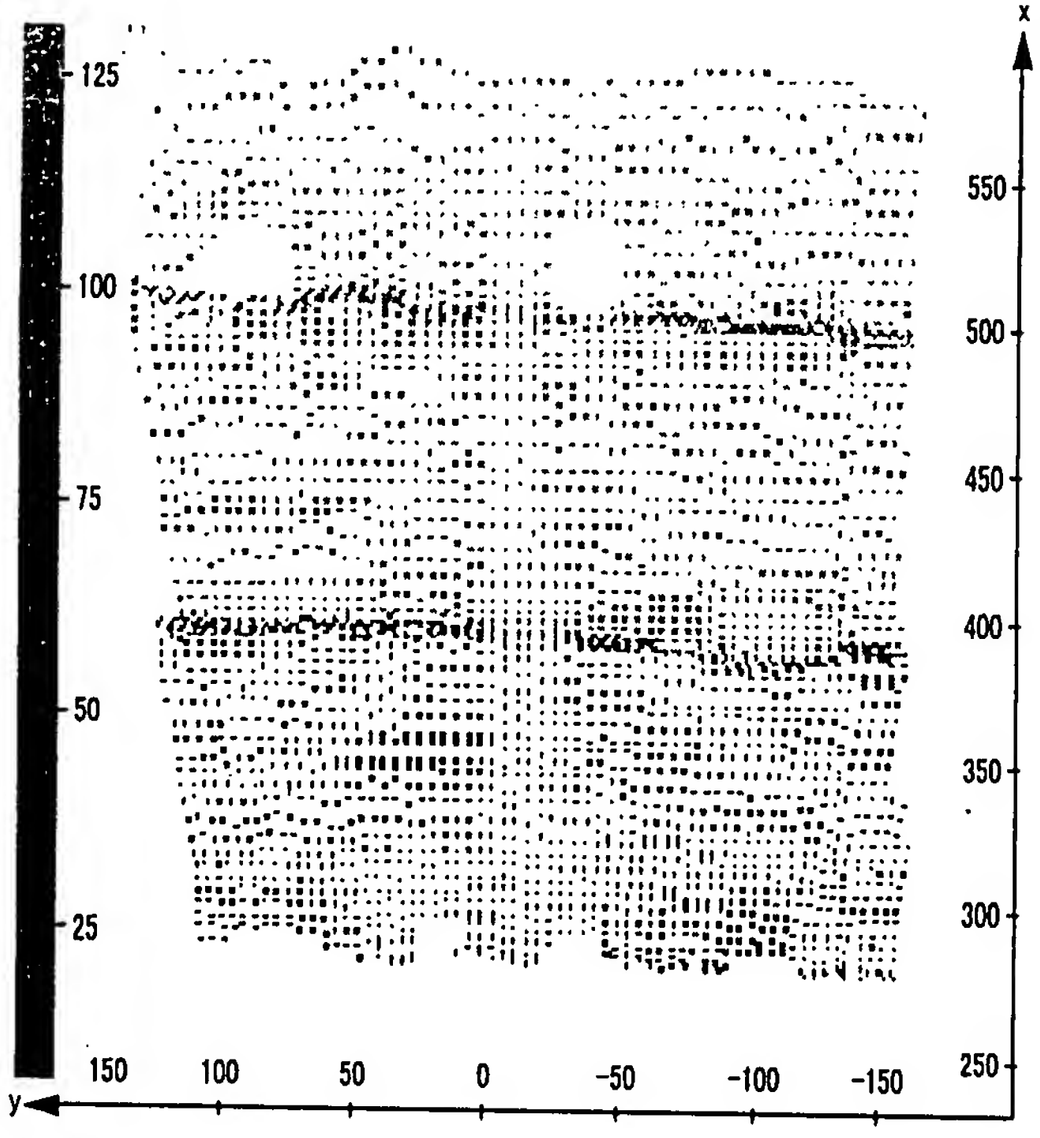


FIG.3B

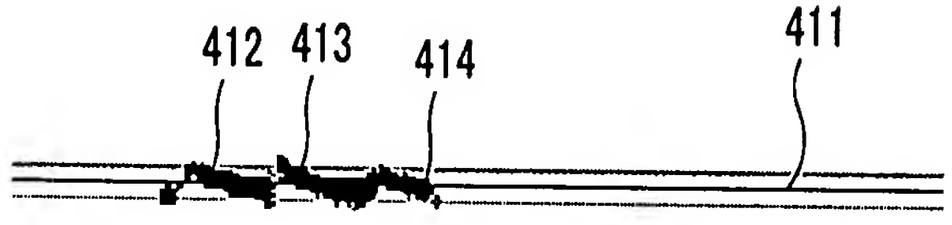


FIG.3D

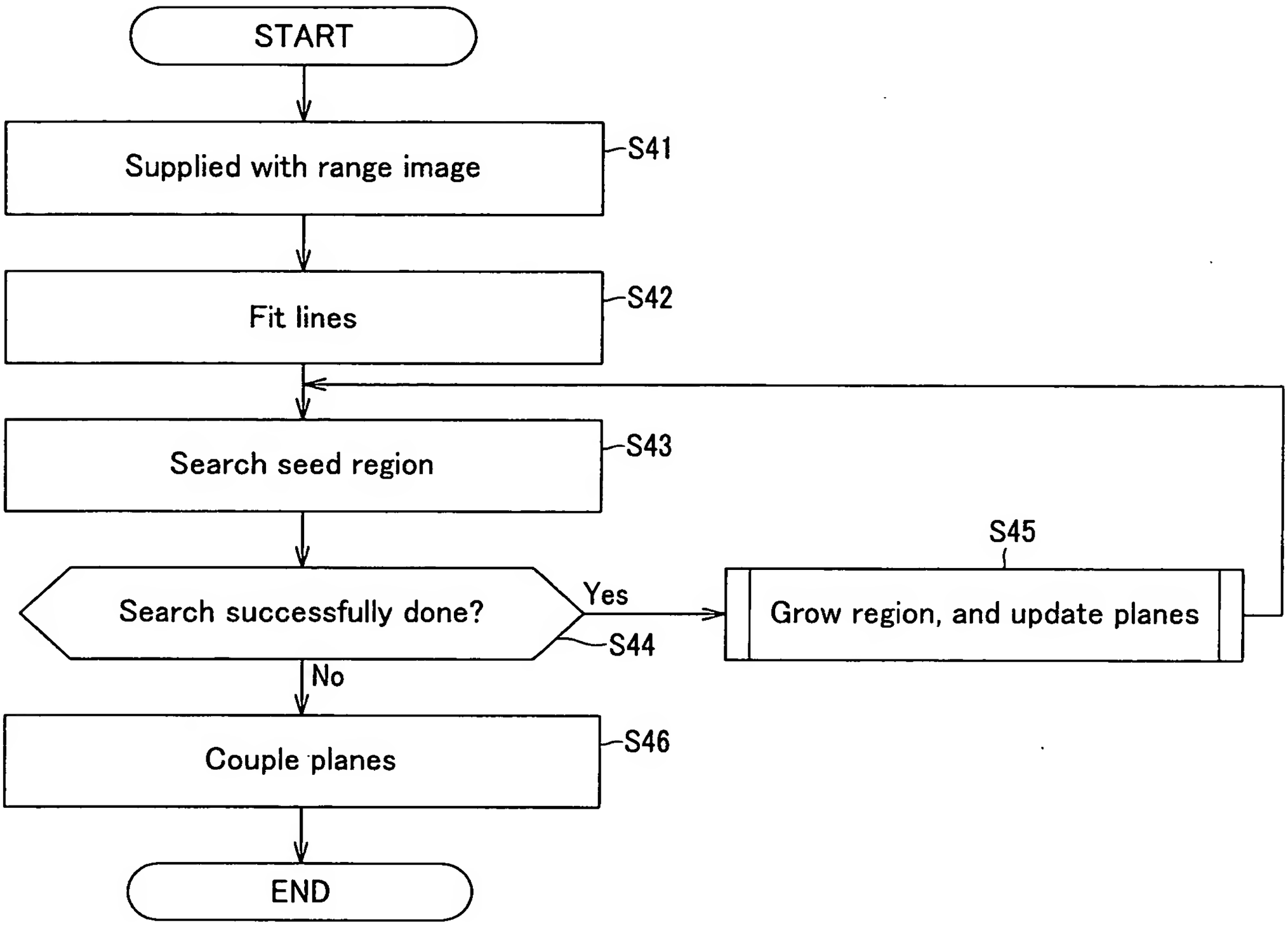

START
Supplied with range image
S41
Fit lines
S42
Search seed region
S43
Search successfully done?
Yes
S44
No
S45
Grow region, and update planes
Couple planes
S46
END

FIG.4

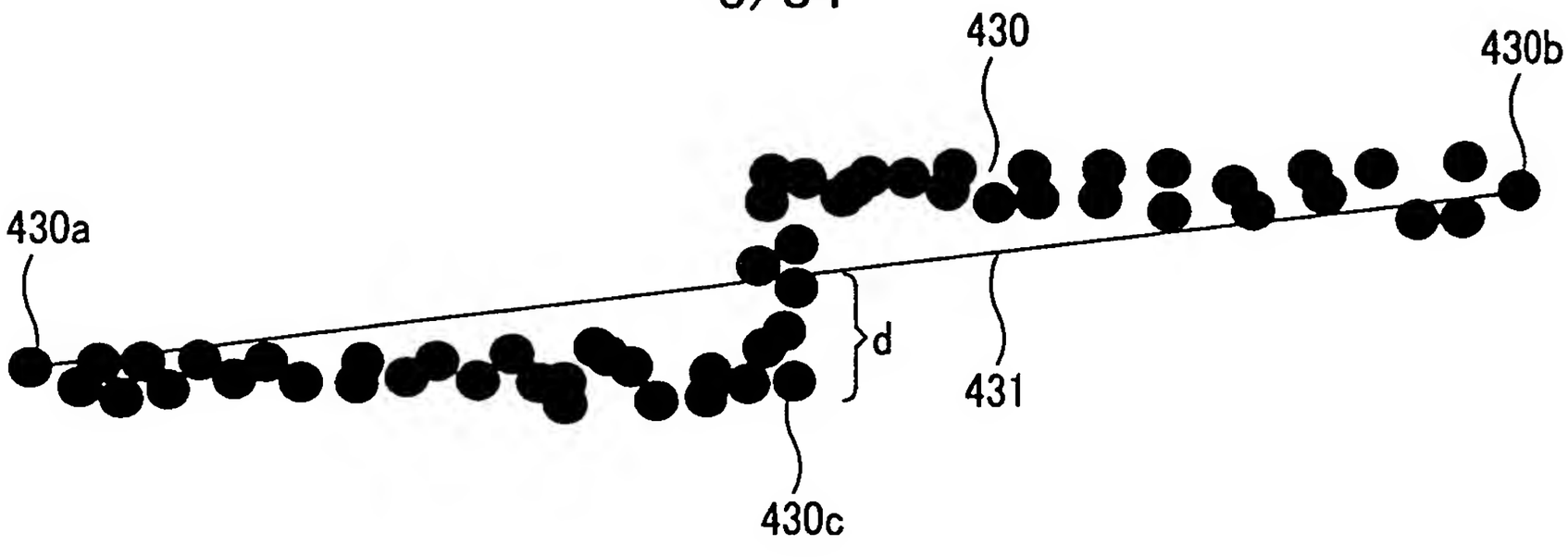


FIG.5A

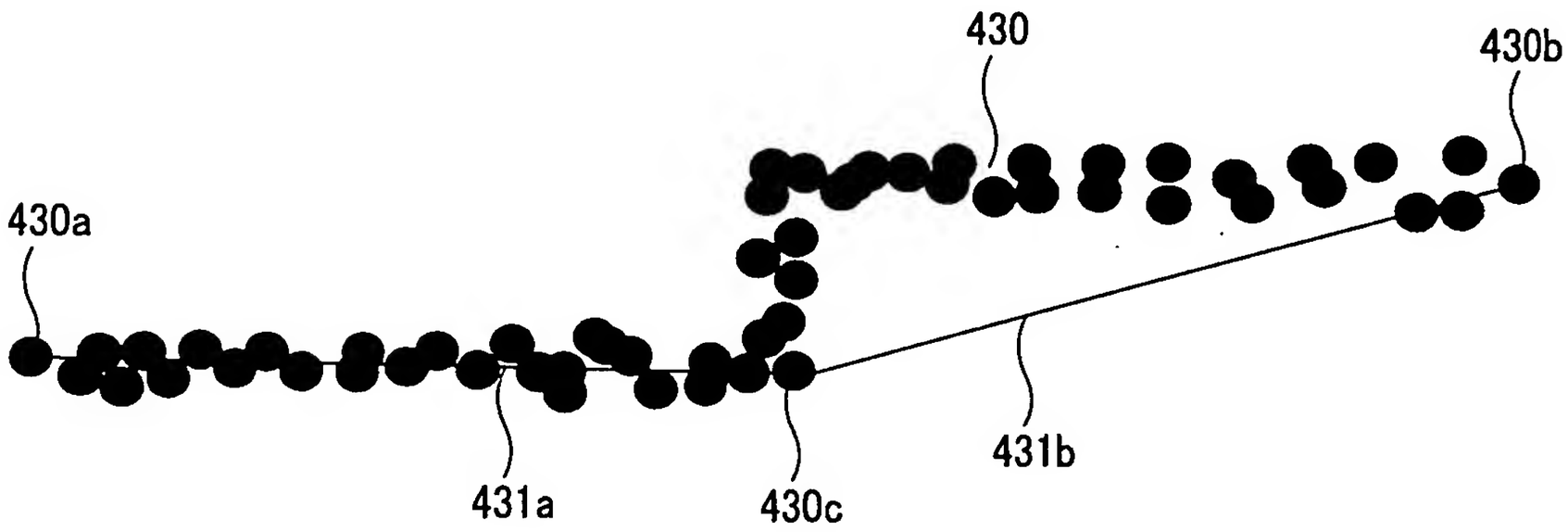


FIG.5B

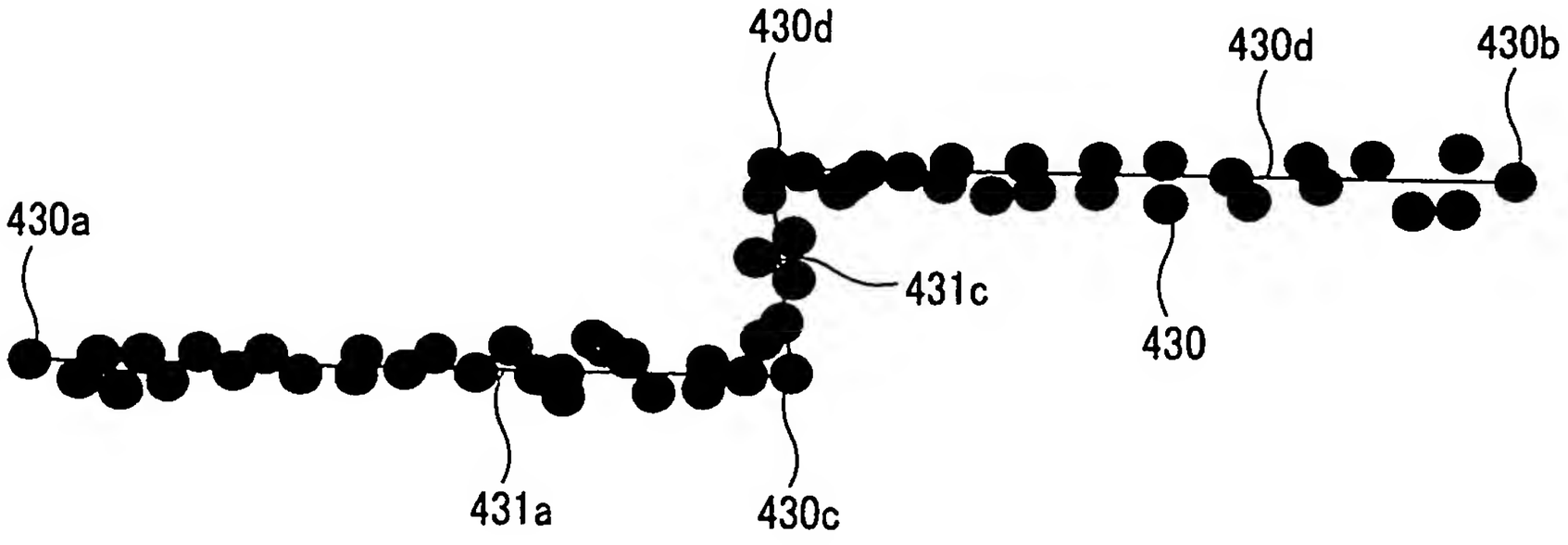


FIG.5C

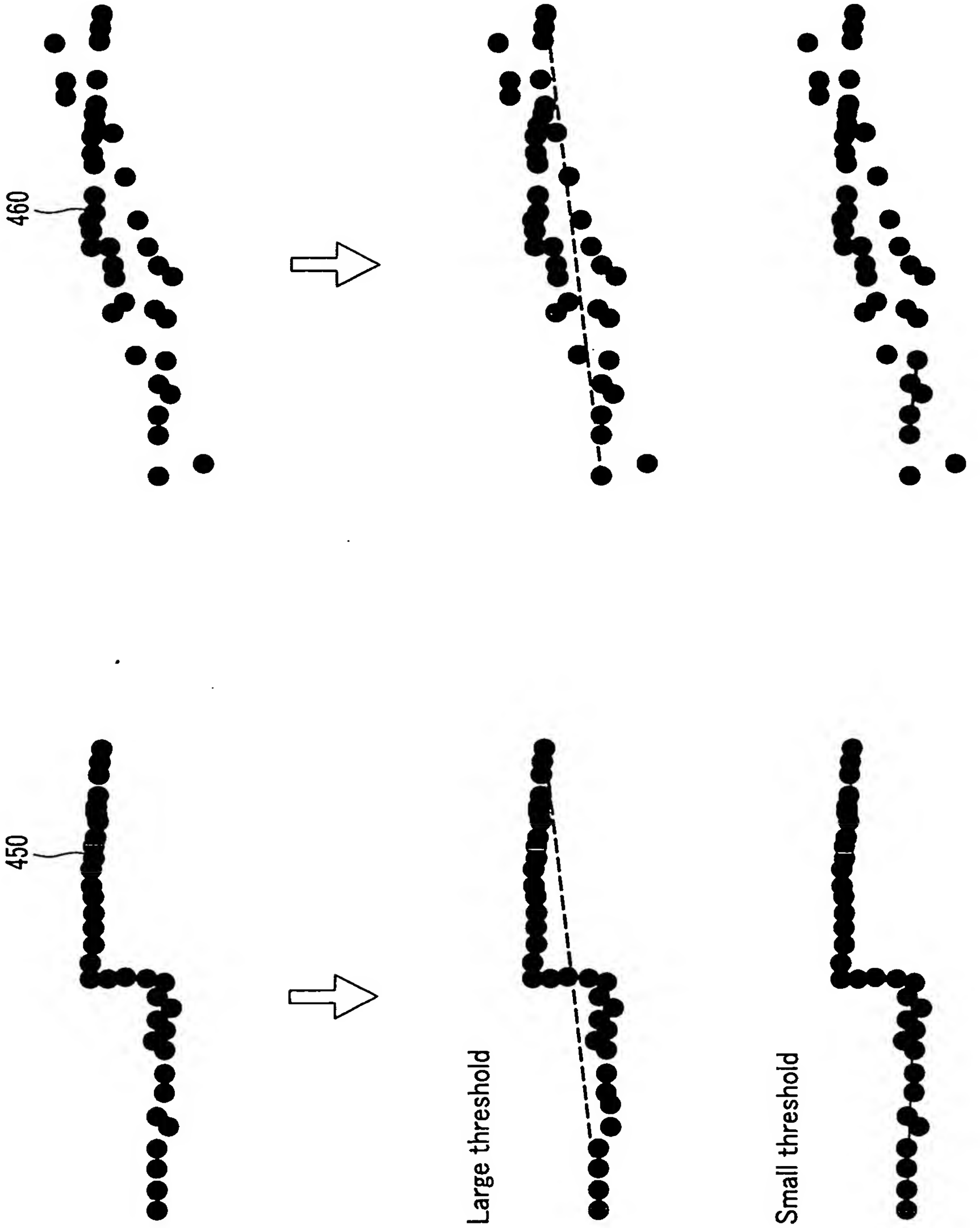


FIG.6A

FIG.6B

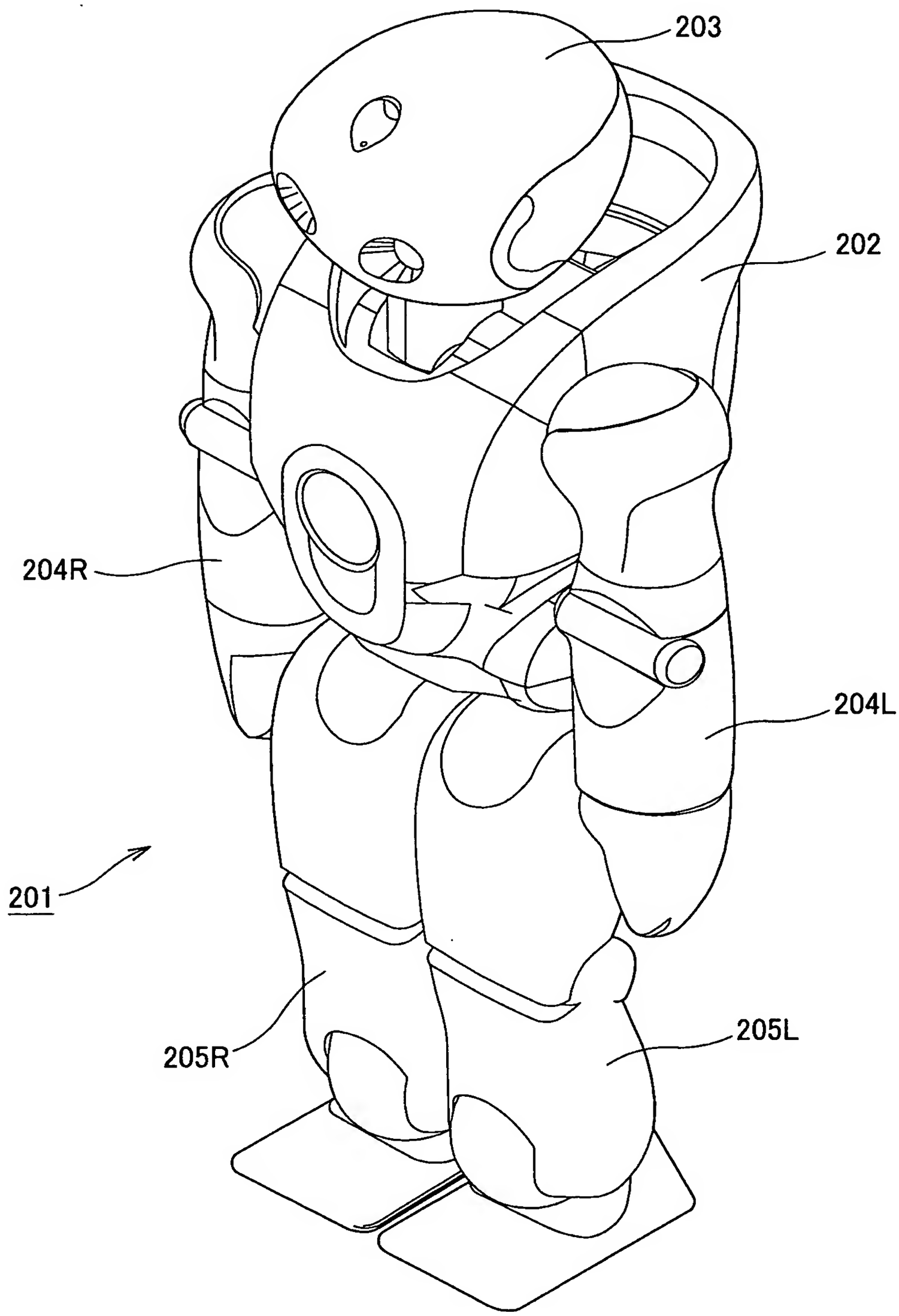


FIG.7

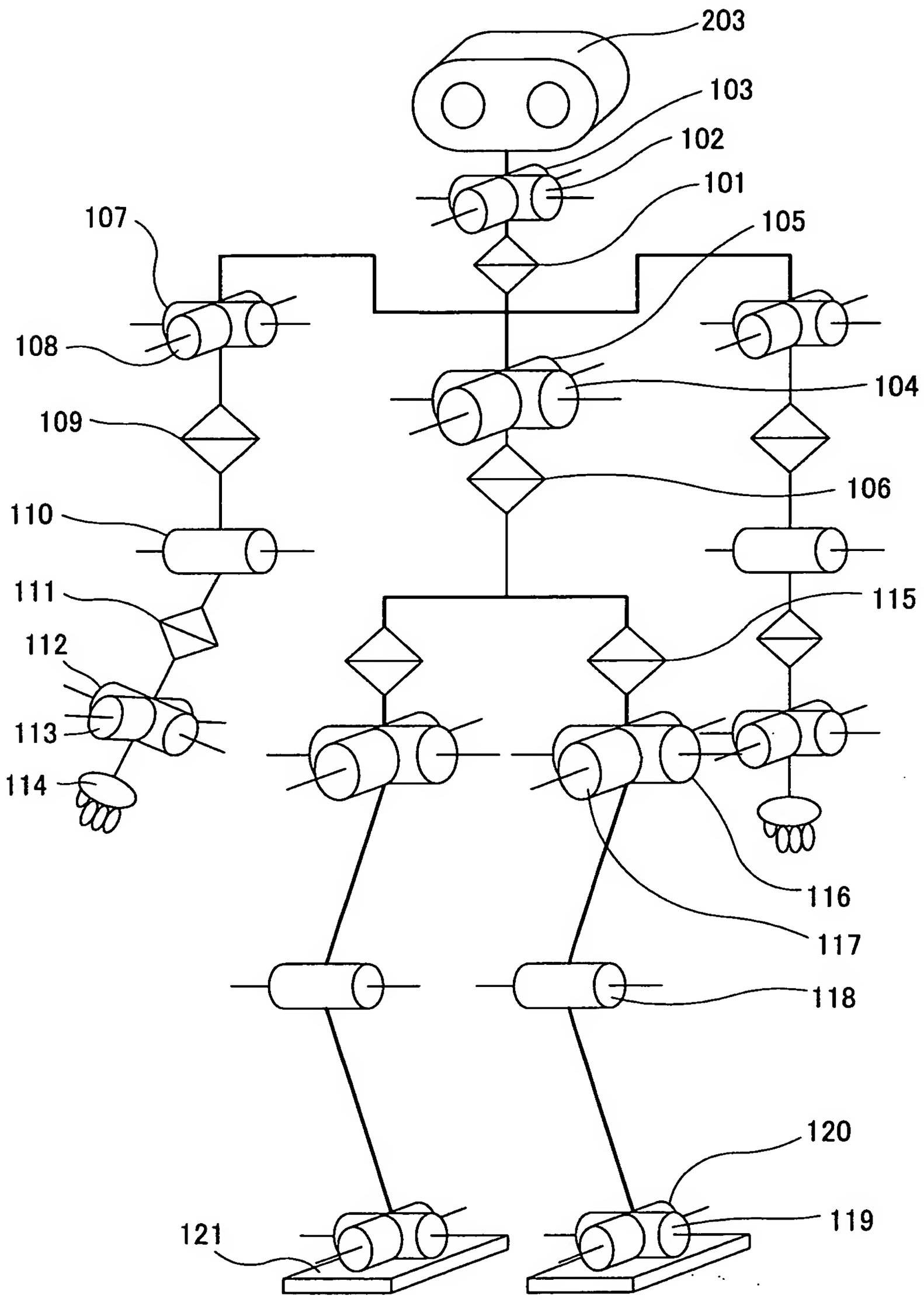

203
103
102
101
107
105
108
104
109
106
110
115
111
112
113
114
116
117
118
120
121
119

FIG.8

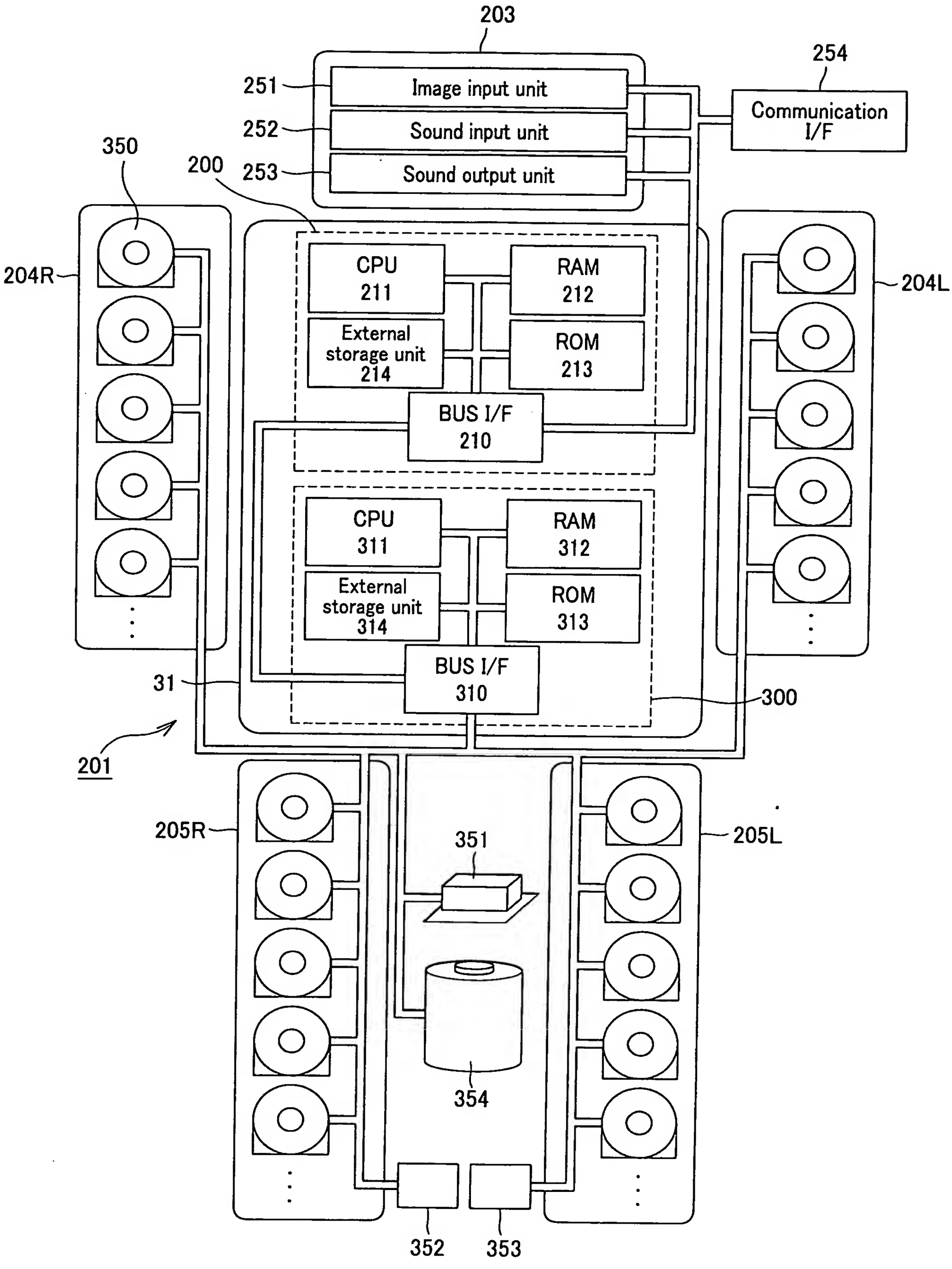

203
251
Image input unit
252
Sound input unit
253
Sound output unit
254
Communication I/F
350
200
204R
204L
CPU 211
RAM 212
External storage unit 214
ROM 213
BUS I/F 210
CPU 311
RAM 312
External storage unit 314
ROM 313
BUS I/F 310
31
300
201
205R
205L
351
354
352
353

FIG.9

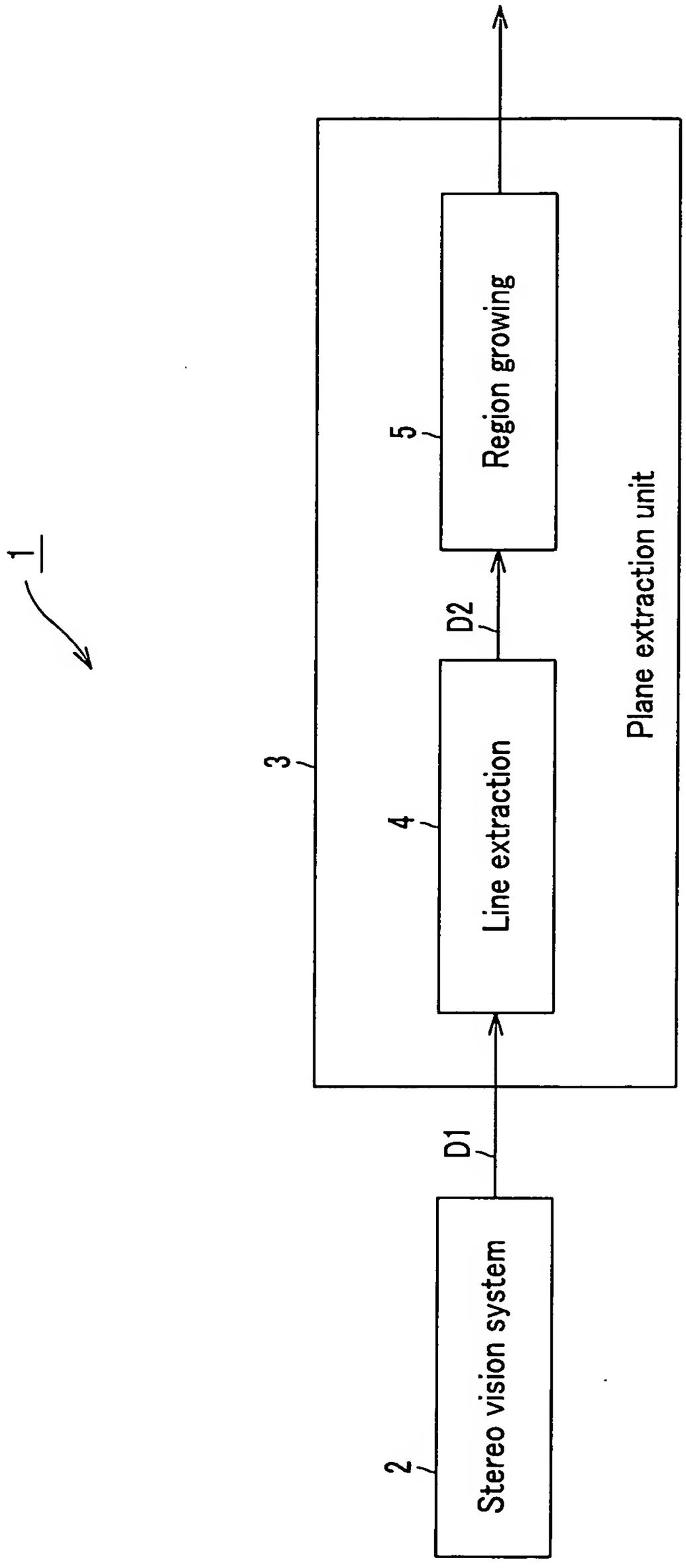

1
2
Stereo vision system
D1
3
Plane extraction unit
4
Line extraction
D2
5
Region growing

FIG.10

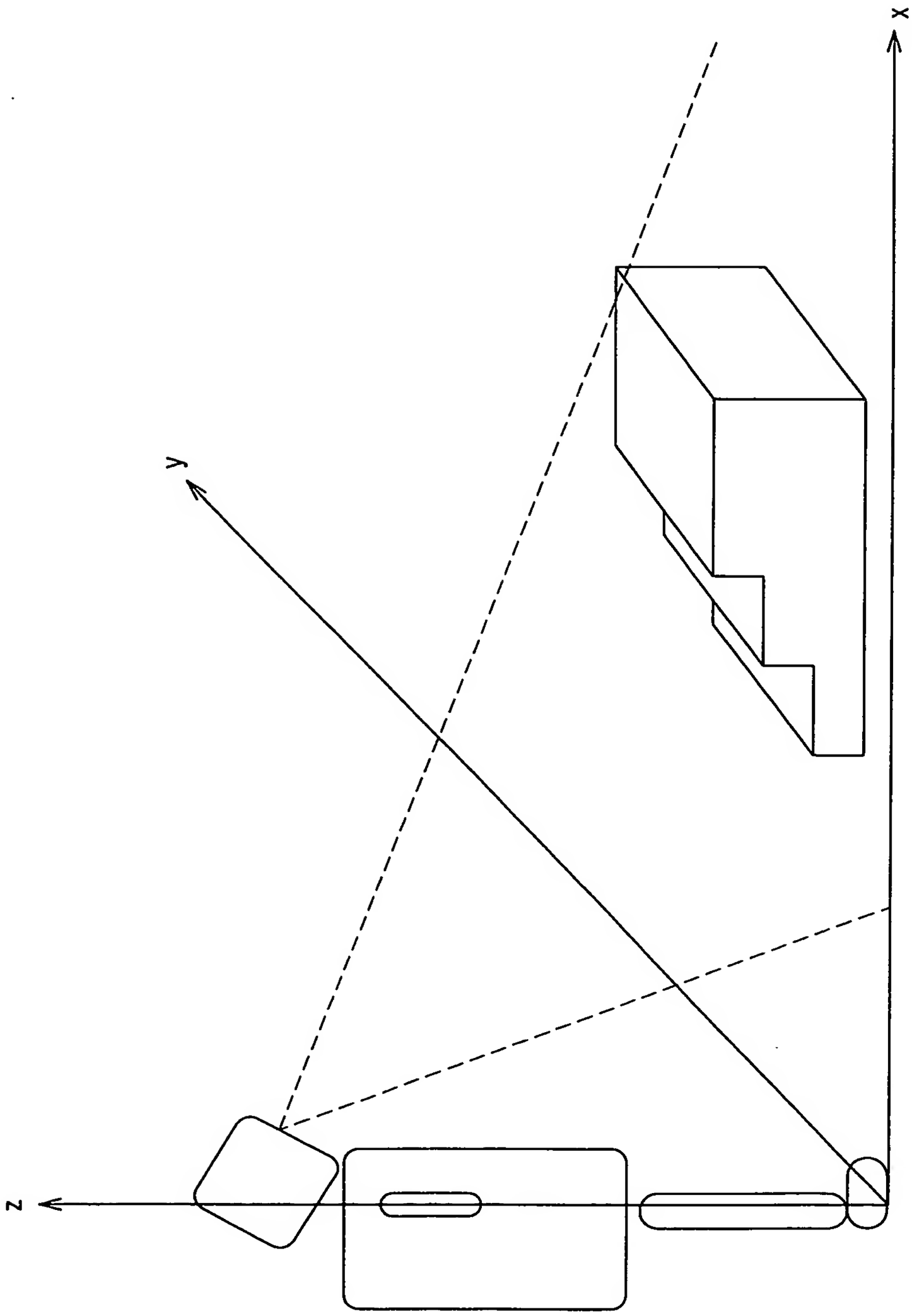


FIG.11

FIG.12A

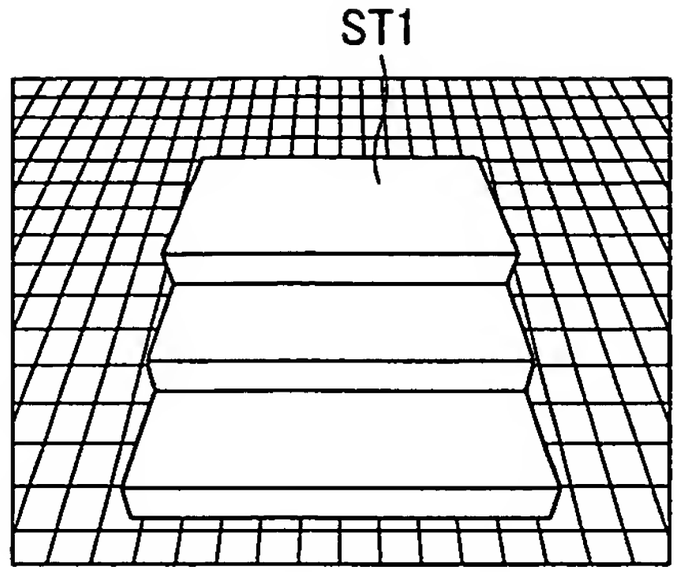


FIG.12B

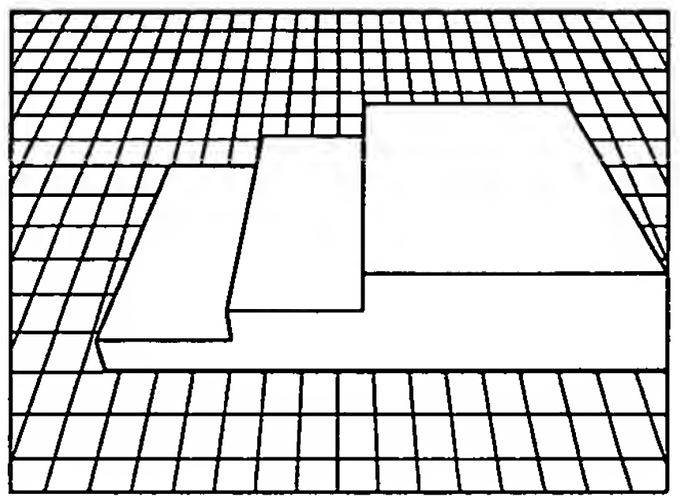
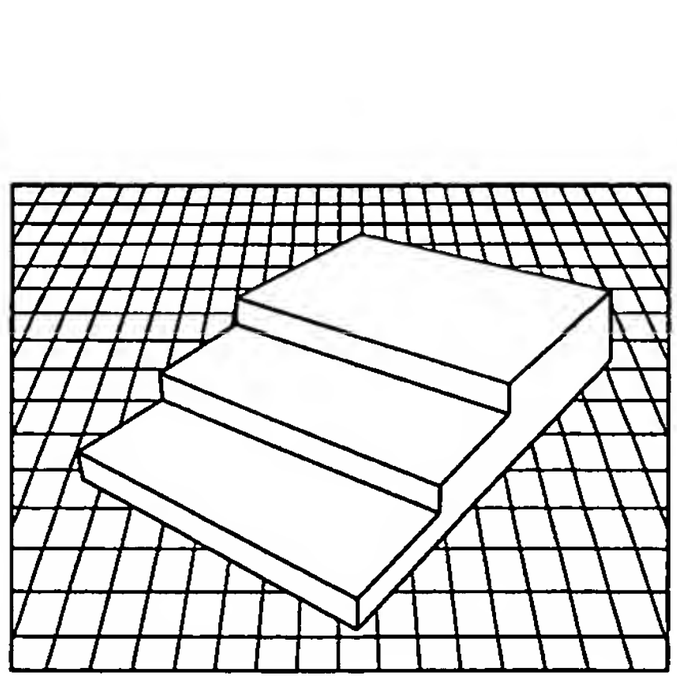


FIG.12C



4cm × 30cm × 10cm/21cm

FIG.13A

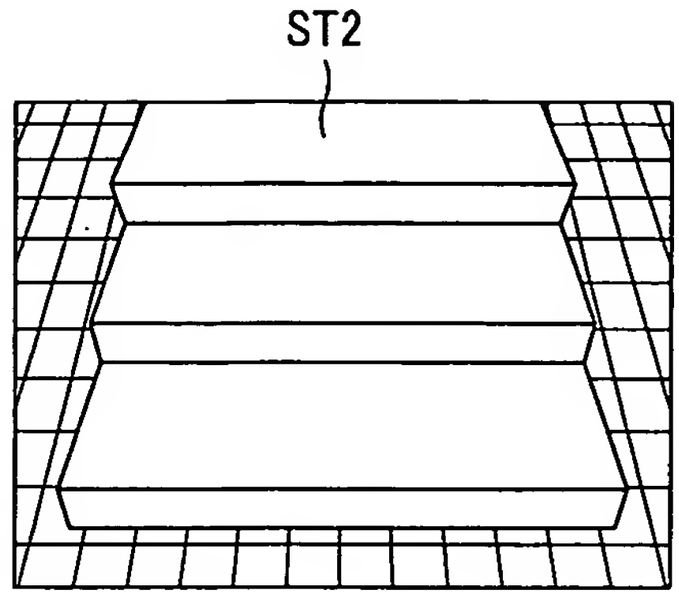


FIG.13B

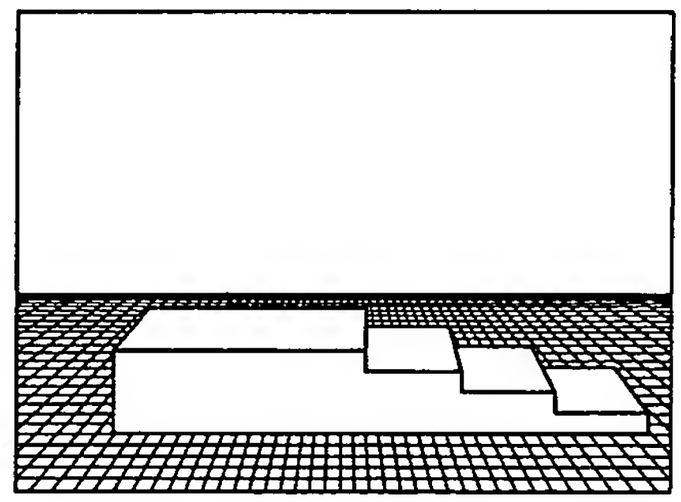
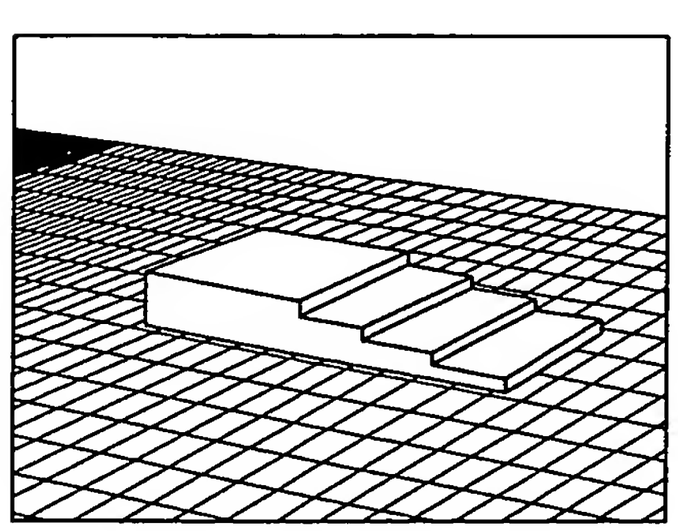


FIG.13C



3cm × 33cm × 12cm/32cm

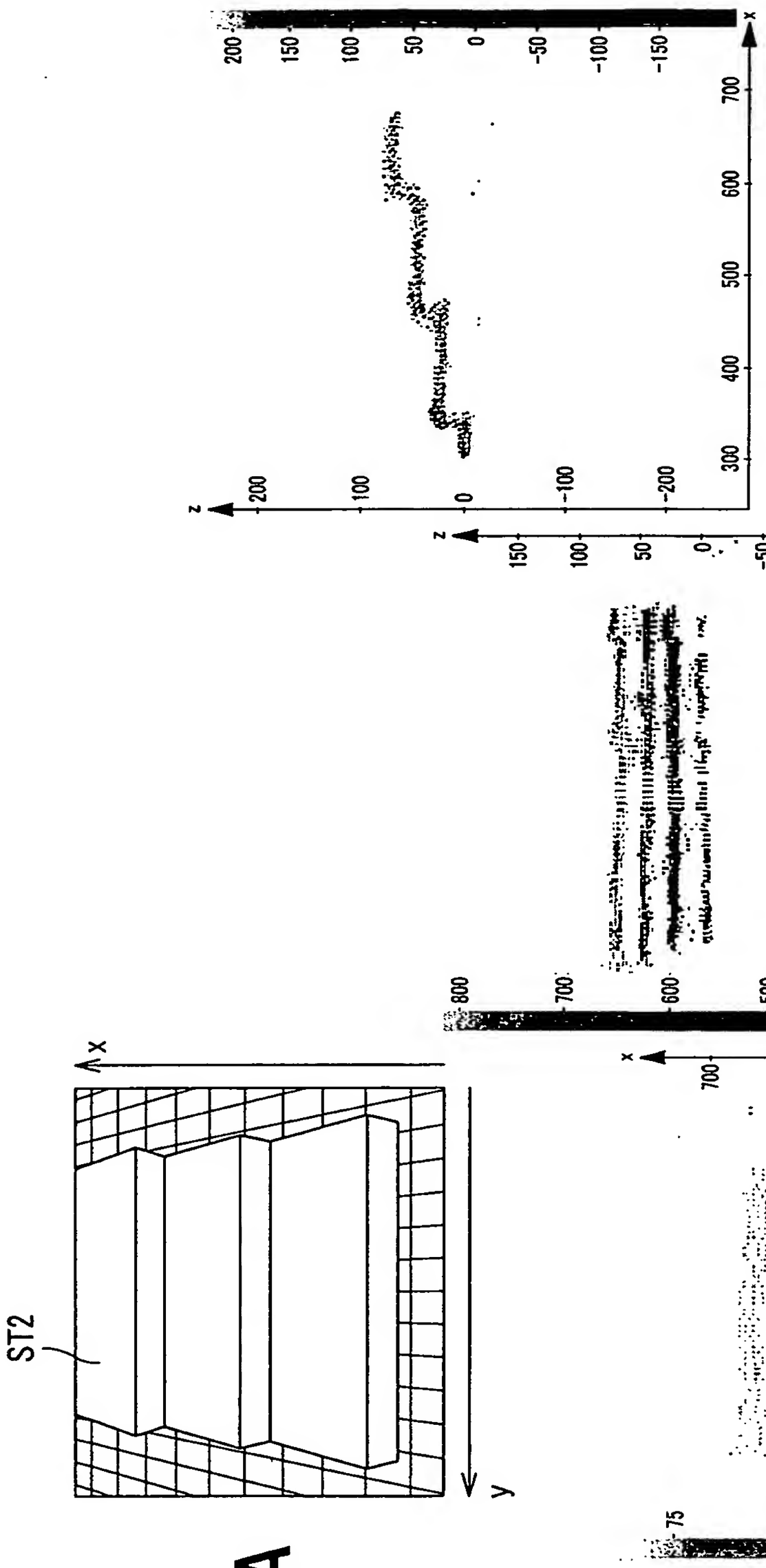


FIG.14A

FIG.14C

FIG.14B

FIG.14D

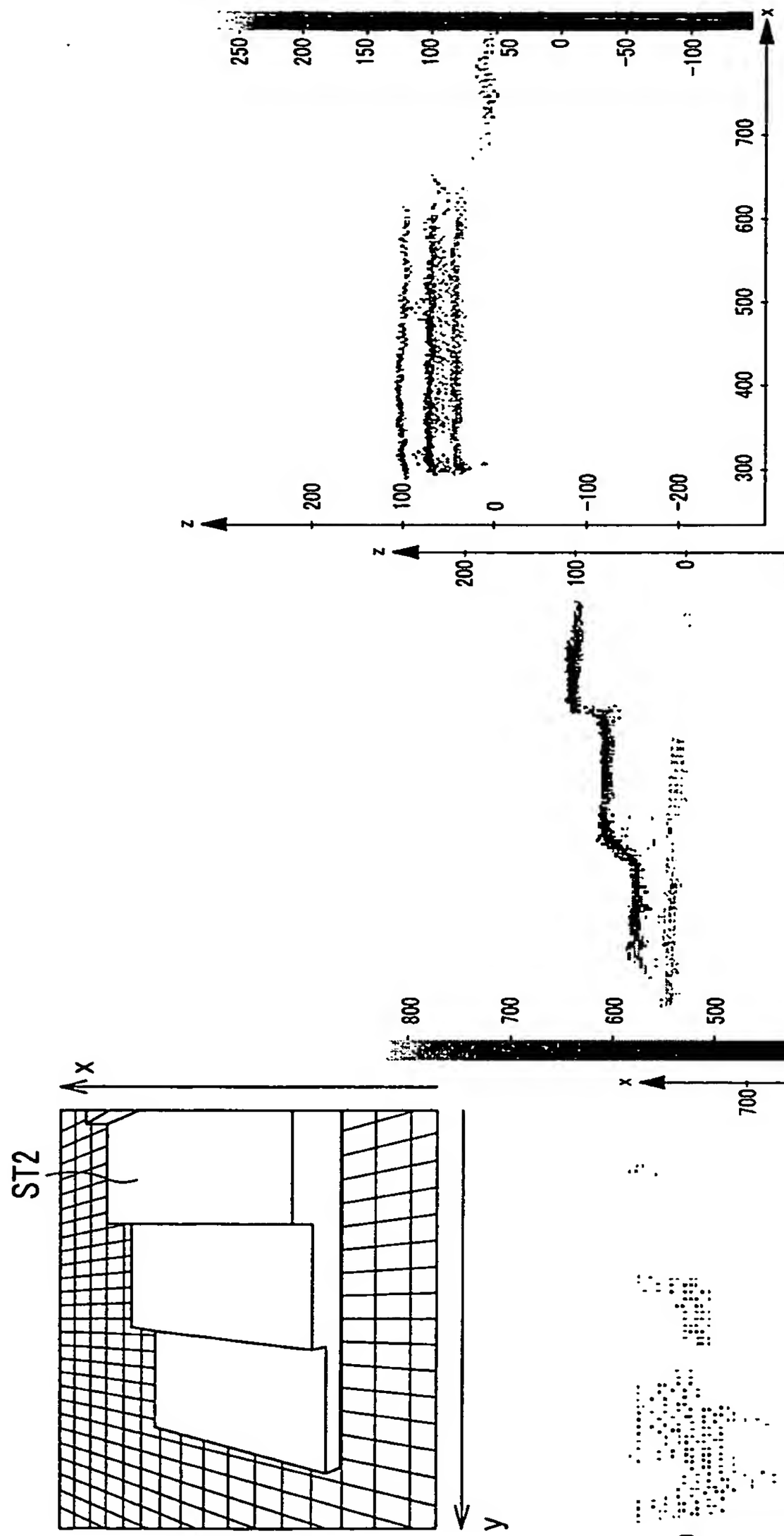


FIG.15A

FIG.15B

FIG.15C

FIG.15D

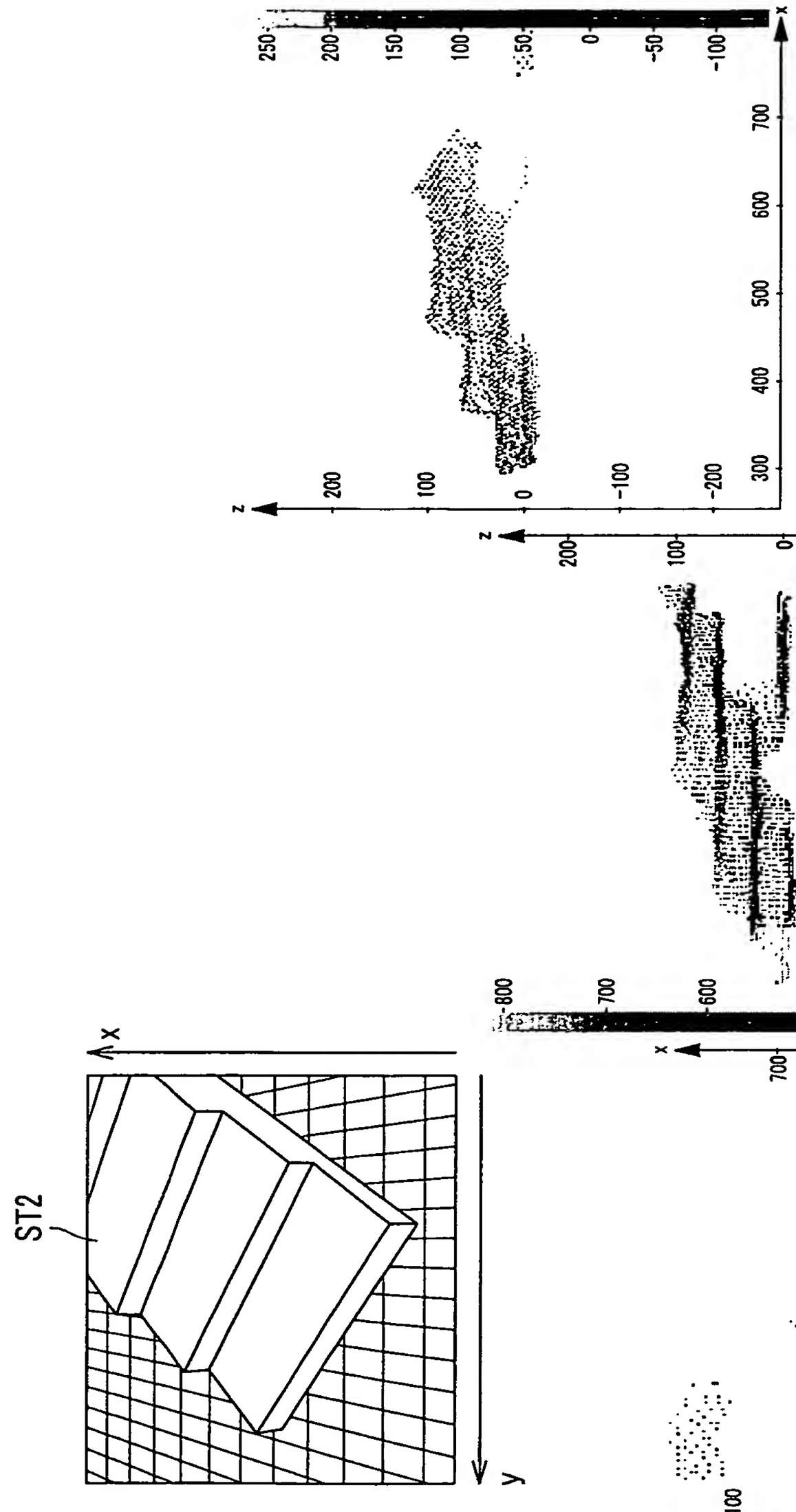


FIG.16A

FIG.16C

FIG.16B

FIG.16D

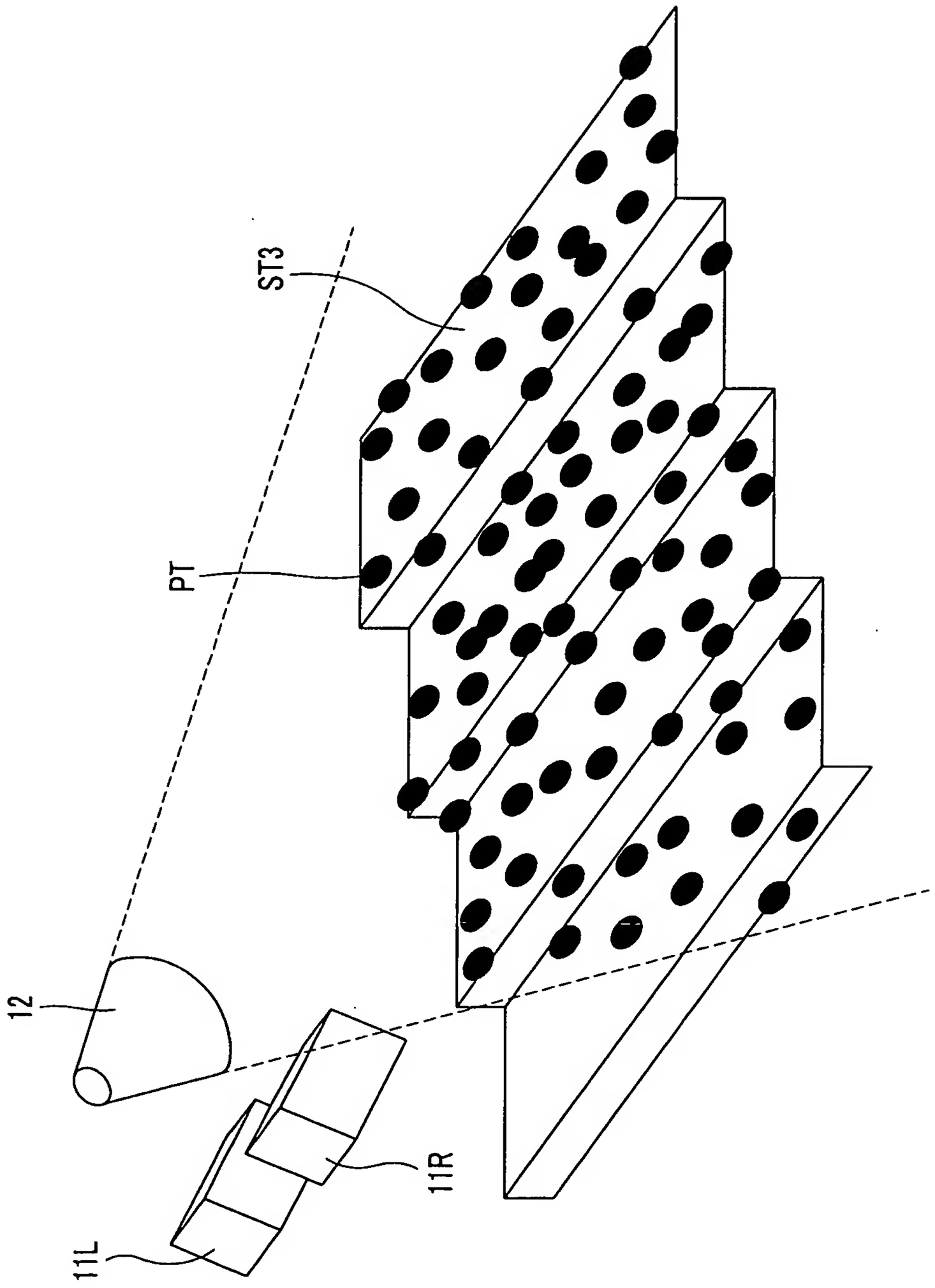


FIG.17

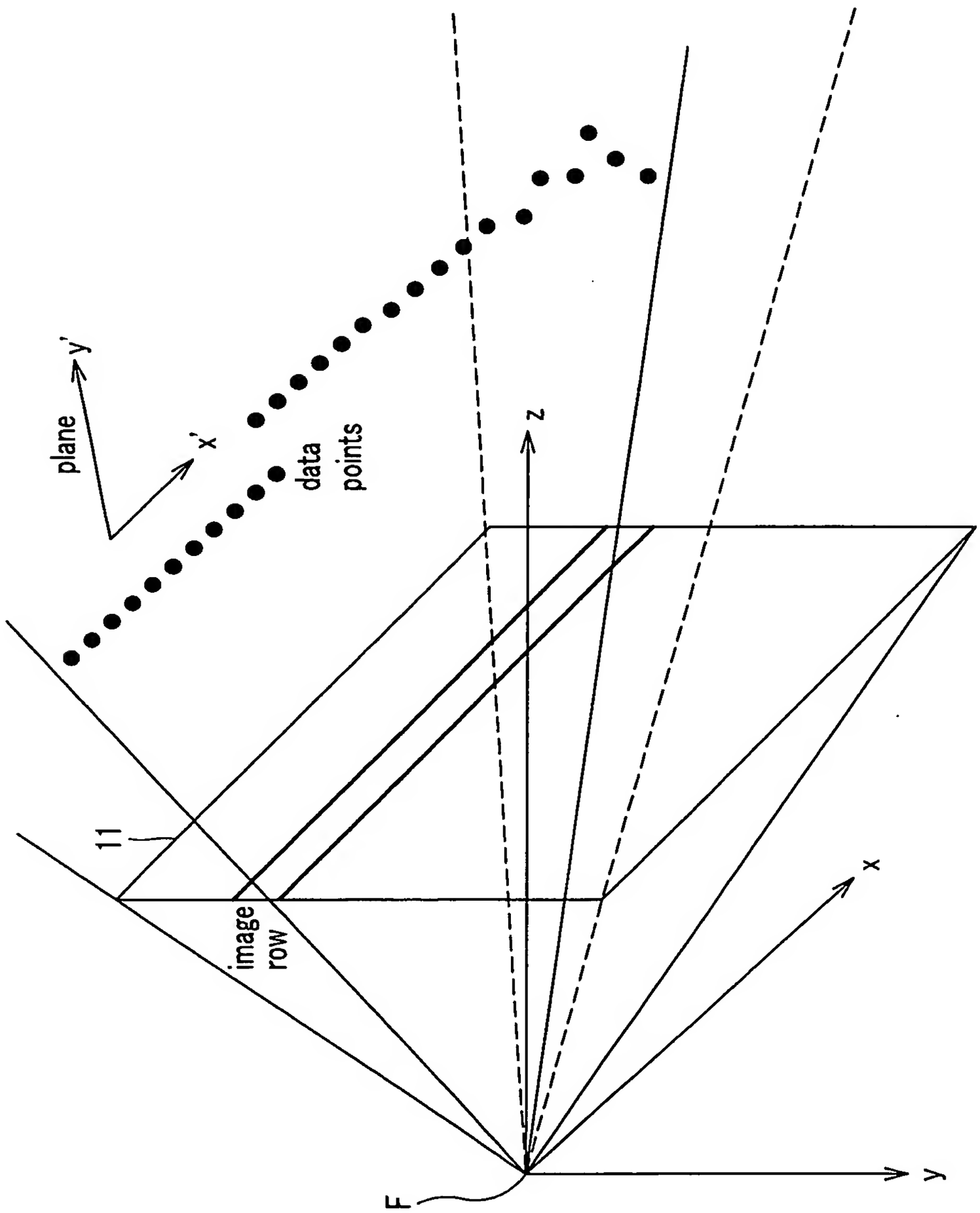


FIG.18

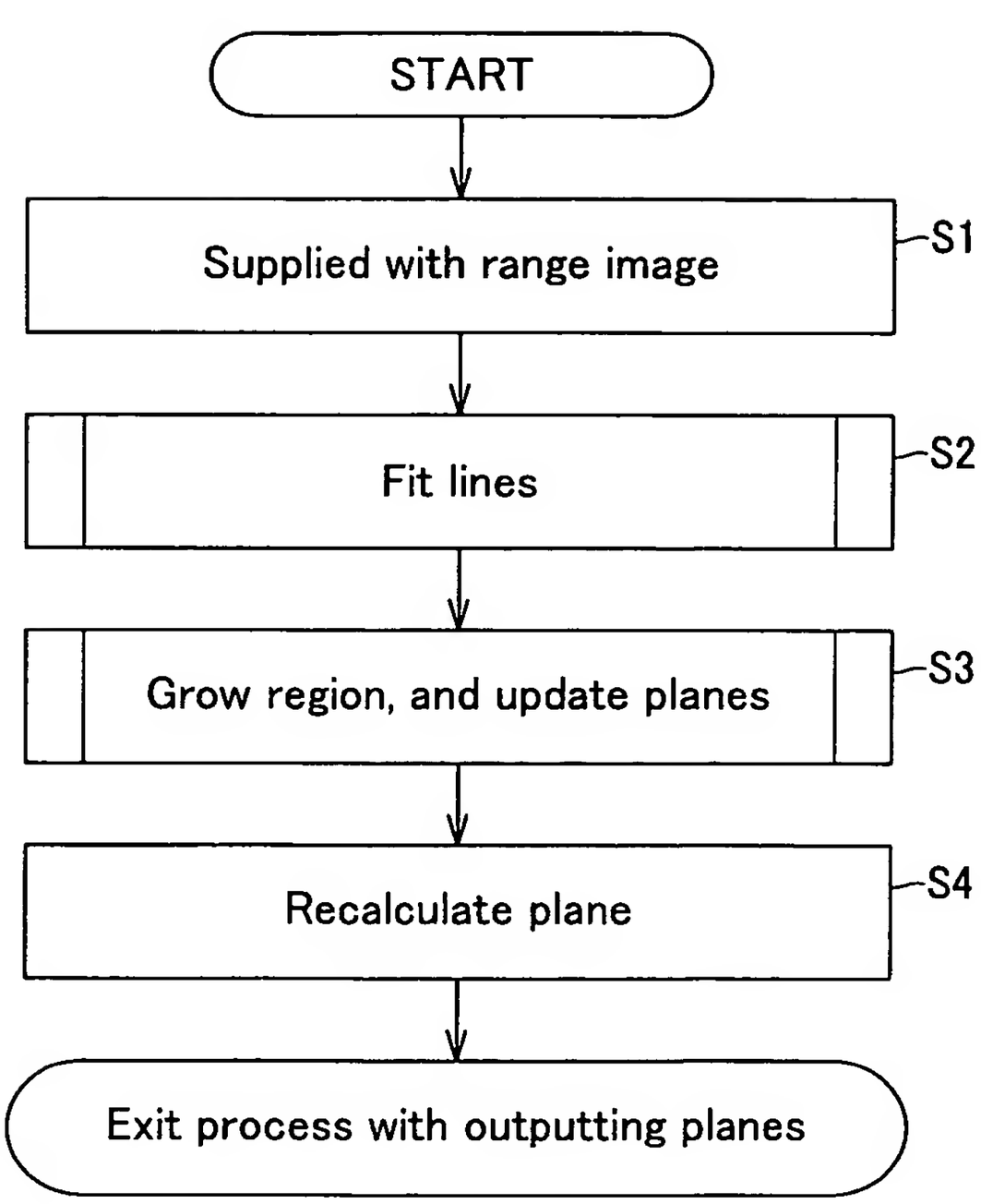

START
Supplied with range image
S1
Fit lines
S2
Grow region, and update planes
S3
Recalculate plane
S4
Exit process with outputting planes

FIG.19

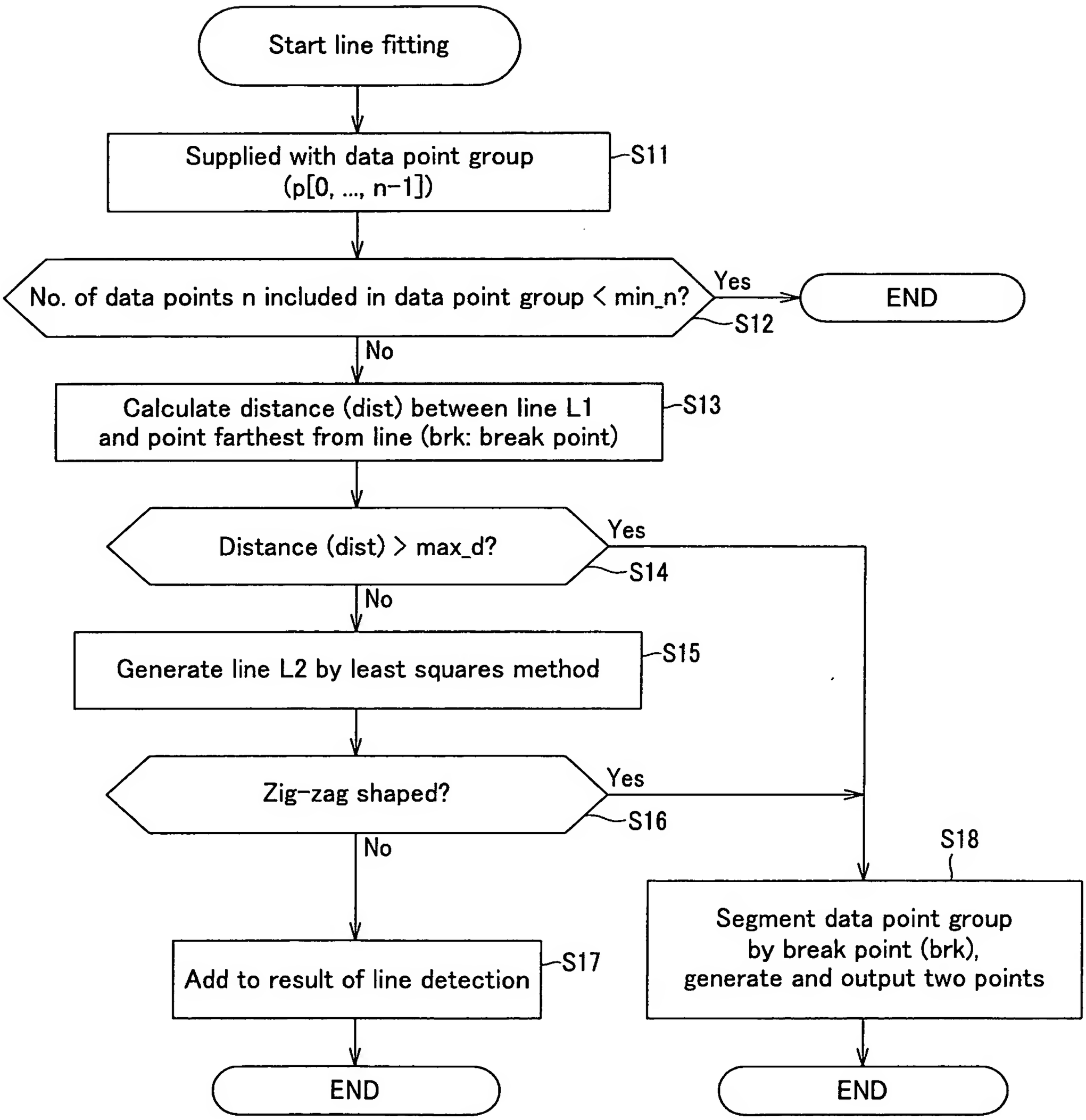
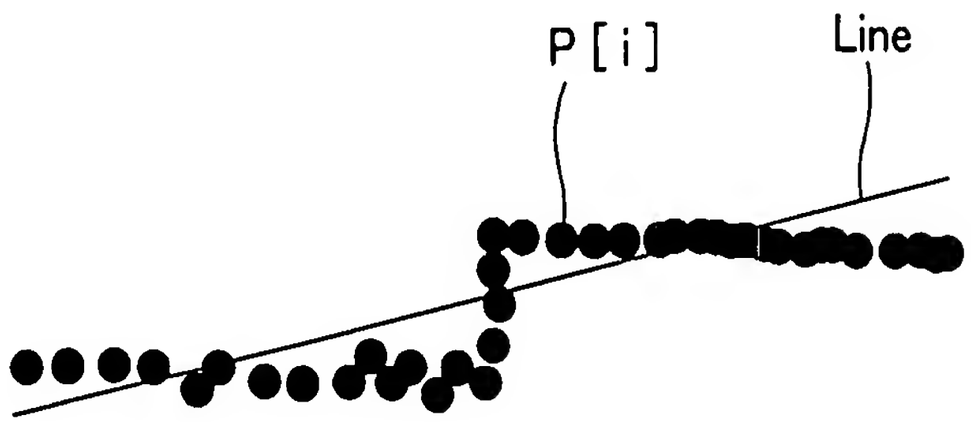
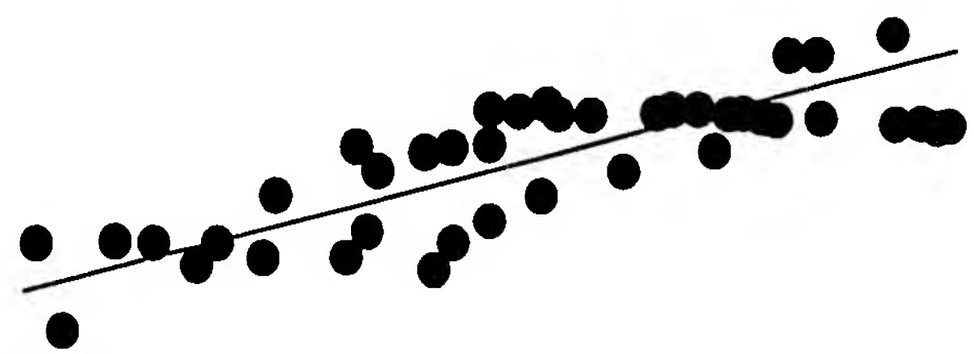

Start line fitting
Supplied with data point group (p[0, ..., n-1])
S11
No. of data points n included in data point group < min_n?
Yes
END
S12
No
Calculate distance (dist) between line L1 and point farthest from line (brk: break point)
S13
Distance (dist) > max_d?
Yes
S14
No
Generate line L2 by least squares method
S15
Zig-zag shaped?
Yes
S16
No
Add to result of line detection
S17
END
S18
Segment data point group by break point (brk), generate and output two points
END

FIG.20



zig-zag-shape

FIG.21A



random

FIG.21B

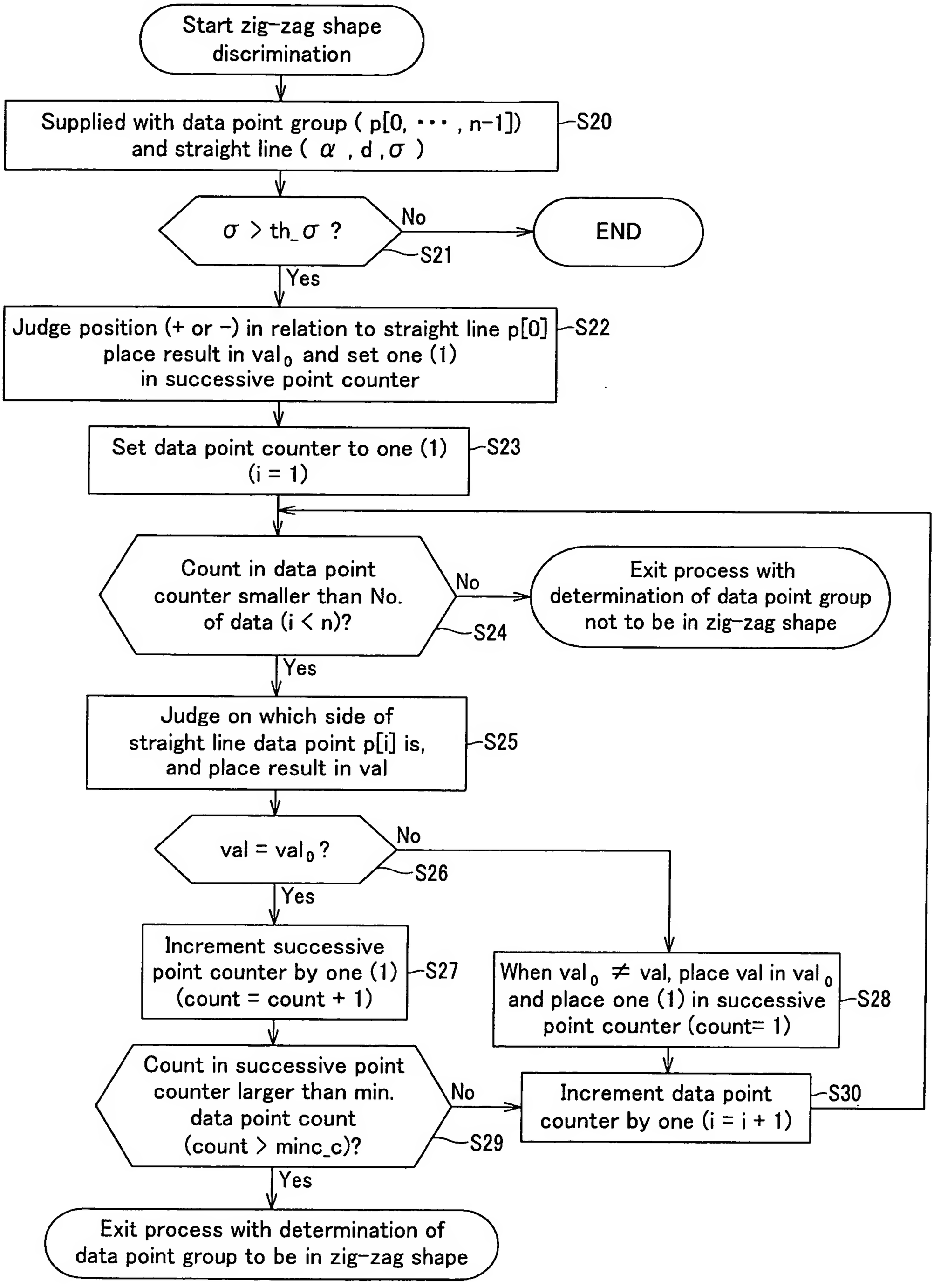

Start zig-zag shape discrimination
Supplied with data point group (p[0, ・・・ , n-1]) and straight line (α , d , σ)
S20
σ > th_σ ?
No
S21
END
Yes
Judge position (+ or -) in relation to straight line p[0] place result in val0 and set one (1) in successive point counter
S22
Set data point counter to one (1) (i = 1)
S23
Count in data point counter smaller than No. of data (i < n)?
No
S24
Exit process with determination of data point group not to be in zig-zag shape
Yes
Judge on which side of straight line data point p[i] is, and place result in val
S25
val = val0 ?
No
S26
Yes
Increment successive point counter by one (1) (count = count + 1)
S27
When val0 ≠ val, place val in val0 and place one (1) in successive point counter (count= 1)
S28
Count in successive point counter larger than min. data point count (count > minc_c)?
No
S29
Increment data point counter by one (i = i + 1)
S30
Yes
Exit process with determination of data point group to be in zig-zag shape

FIG.22

Input: *pts* : vector of points, *n* : number of points, α, d, σ : parameters and std-dev of fitted line.

Output : true if curve contains a *zig-zag*- shape, false otherwise.

Sequence :

```
    if σ > threshσ  then
    val0 = pts[0].x* cos α + pts[0].y* sin α + d
    count = 1
      for i = 1 to (n-1) do
          val = pts[i].x* cos α + pts[i].y* sin α + d
          if (val* val0 <=0) then
              val0 = val
              count = 1
          else
              count = count + 1
              if (count >= min-points-for-zig-zag-shape ) then
                  return true
              endif
          endif
      endfor
endif
return false
```

FIG.23

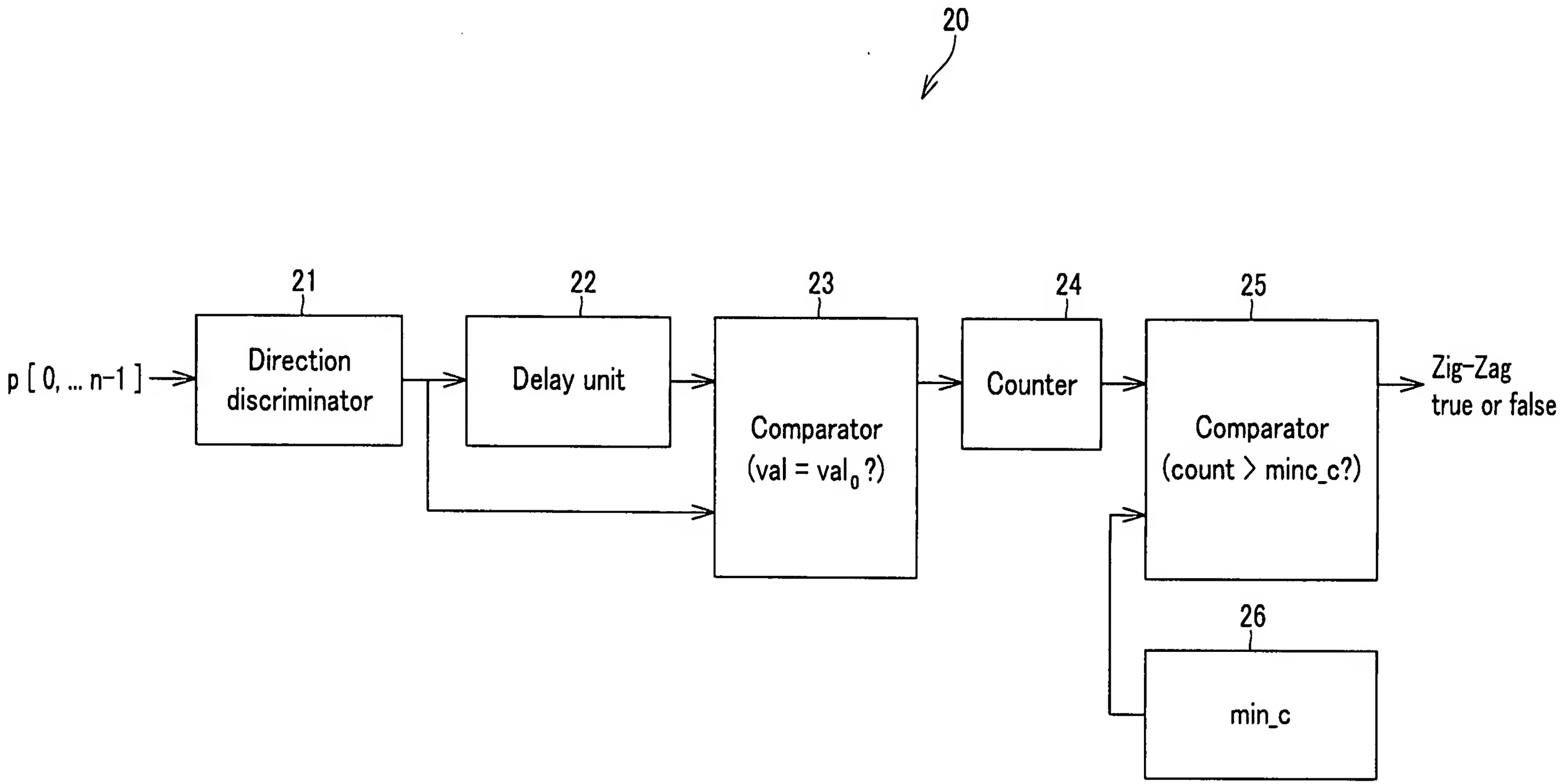

20
21
22
23
24
25
p [0, ... n-1]
Direction discriminator
Delay unit
Comparator (val = val0 ?)
Counter
Comparator (count > minc_c?)
Zig-Zag true or false
26
min_c

FIG.24

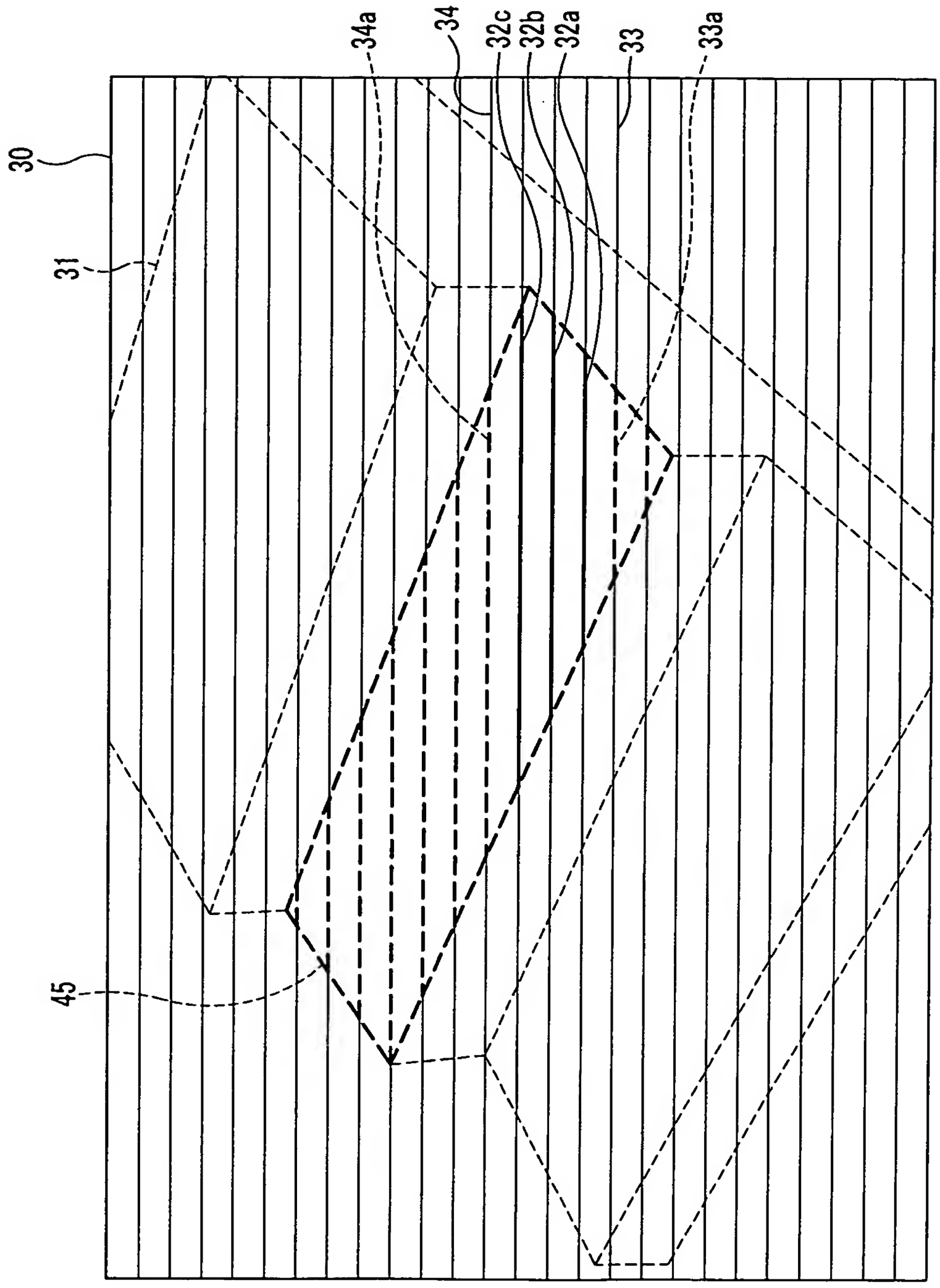


FIG.25

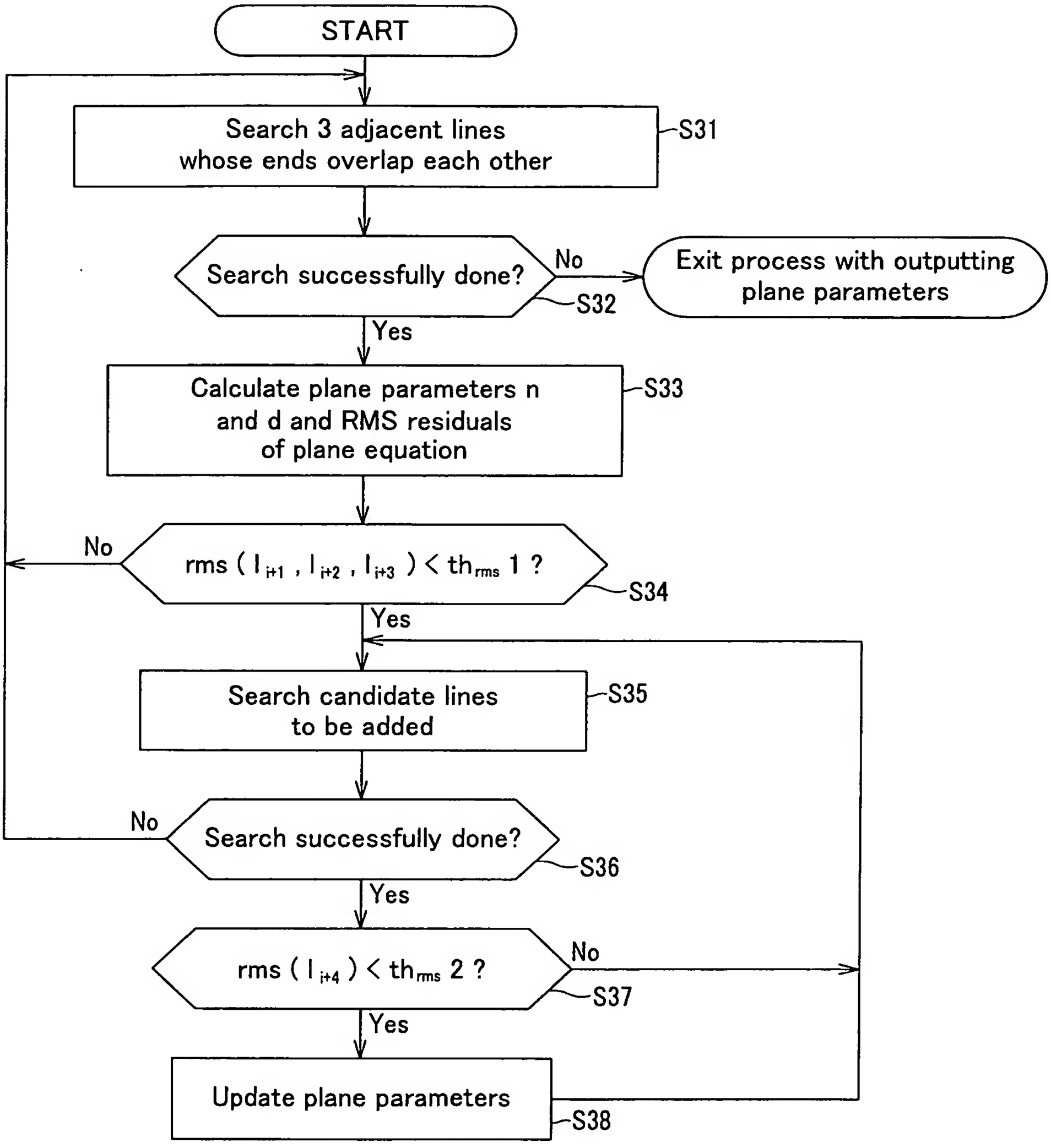

START
Search 3 adjacent lines whose ends overlap each other
S31
Search successfully done?
No
S32
Exit process with outputting plane parameters
Yes
Calculate plane parameters n and d and RMS residuals of plane equation
S33
No
rms (I i+1 , I i+2 , I i+3) < th rms 1 ?
S34
Yes
Search candidate lines to be added
S35
No
Search successfully done?
S36
Yes
rms (I i+4) < th rms 2 ?
No
S37
Yes
Update plane parameters
S38

FIG.26

FIG.27B

FIG.27A

Algorithm *FindSeedRegion*

Input: *lines[i]*: vector of lines for esch image row (or column) i,

n: number of image rows (or columns)

Output : set of lines (seed region) or empty set (no seed found).

Sequence :

```
for i = 0 to (n-3) do
    for l1 in lines[i] do
        for l2 in lines[i+1] do
            for l3 in lines[i+2] do
                if overlap(l1 , l2 ) and overlap(l2 , l3 ) then
                    (n,d) = fitPlane(l1 , l2 , l3 )
                    if rms(l1 , l2 , l3 ) < thresh1rms then
                        seed = {l1 , l2 , l3 }
                        remove(l1 , l2 , l3 )
                        return seed
                    endif
                endif
            endfor
        endfor
    endfor
endfor
return {}
```

FIG.28

Algorithm *RegionGrowing*

Input: *region* : set of lines as seed region,

lines[i] : vector of lines for esch image row (or column) i,

n : number of image rows (or columns)

Sequence :

A = 0, b = 0

for *1 in region* do *(A,b) = add(A,b,l)* endfor

(n,d) = solve(A,b)

open = region

while *not empty(open)* do

l_1 *= select(open),open = open - {*l_1*}*

for *i in neighbor(index(*l_1*))* do

for l_2 *in lines[i]* do

if *overlap(*l_1*,*l_2*)* and *rms(*l_2*) < thresh2*$_{rms}$ then

region = region + {l_2*},*

(A,b) = add(A,b,l_2*), (n,d) = solve(A,b)*

open = open + {l_2*},*

remove(l_2*)*

endif

endfor

endfor

endfor

plane = {n,d,A,b,region}

planes = planes + {plane}

FIG.29

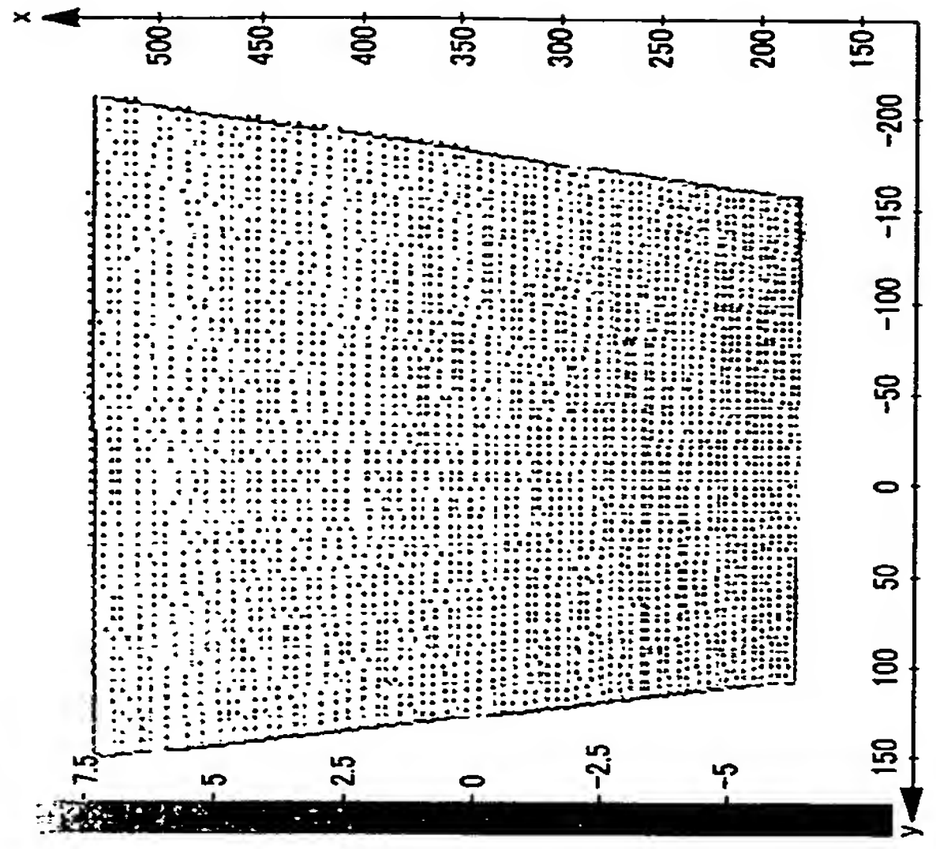


FIG.30C

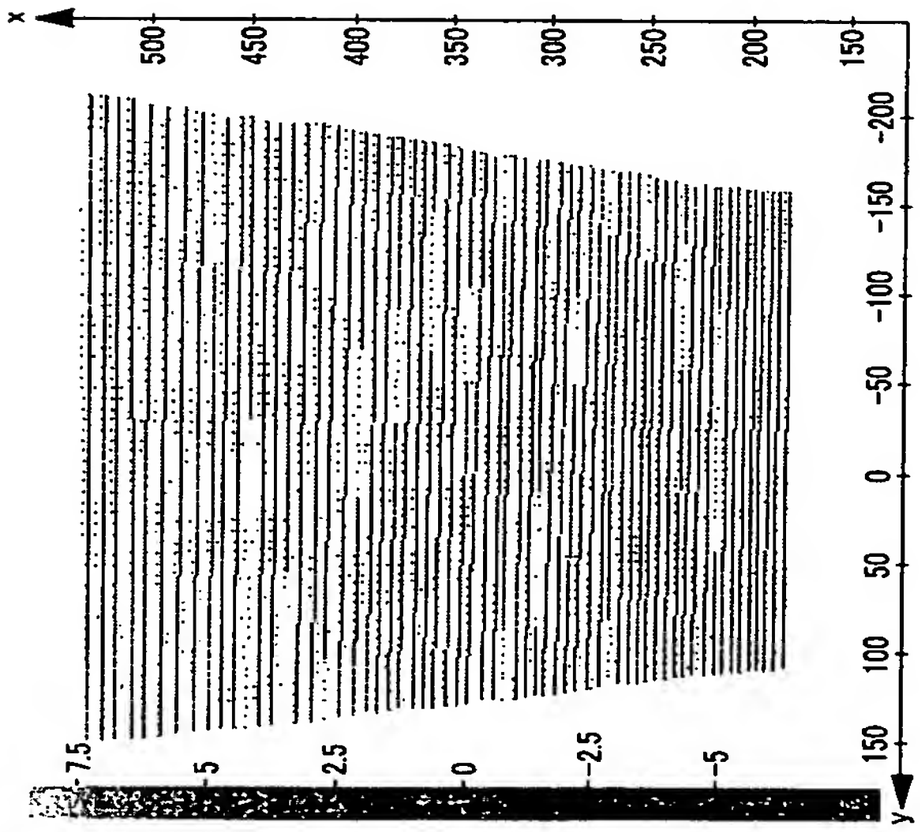


FIG.30B

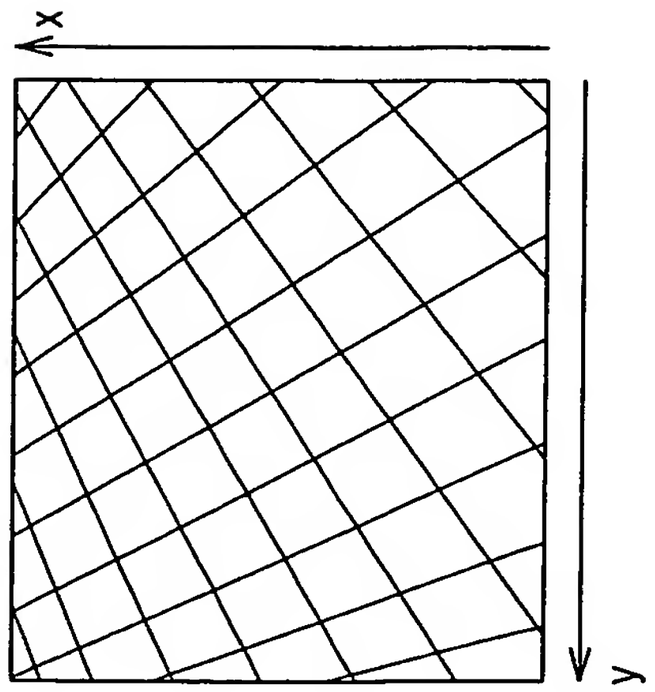


FIG.30A

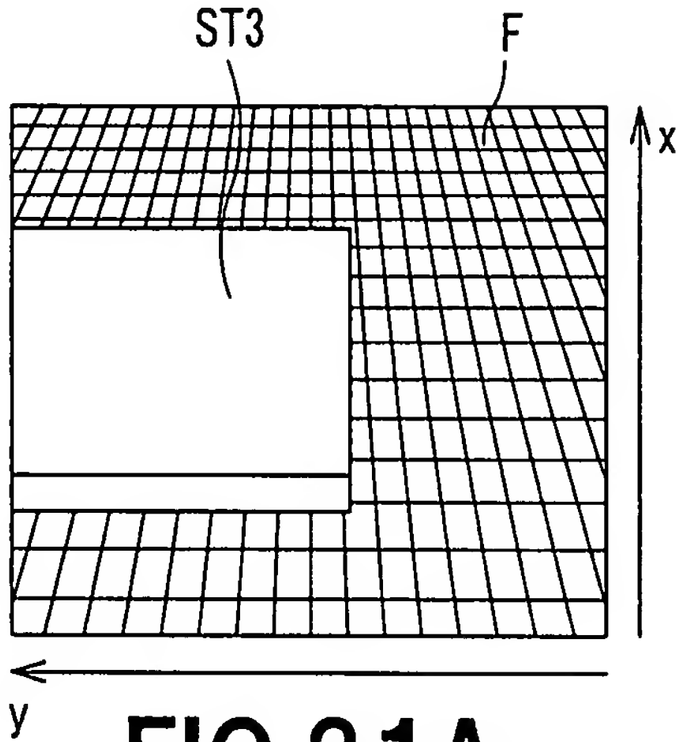


FIG.31A

No	max_d	enable zig-zag	correct extraction (horizontal)	correct extraction (vertical)
1	30	no	0 / 10	0 / 10
2	25	no	0 / 10	0 / 10
3	20	no	10 / 10	0 / 10
4	15	no	10 / 10	3 / 10
5	10	no	10 / 10	10 / 10
6	30	yes	10 / 10	10 / 10

FIG.31B

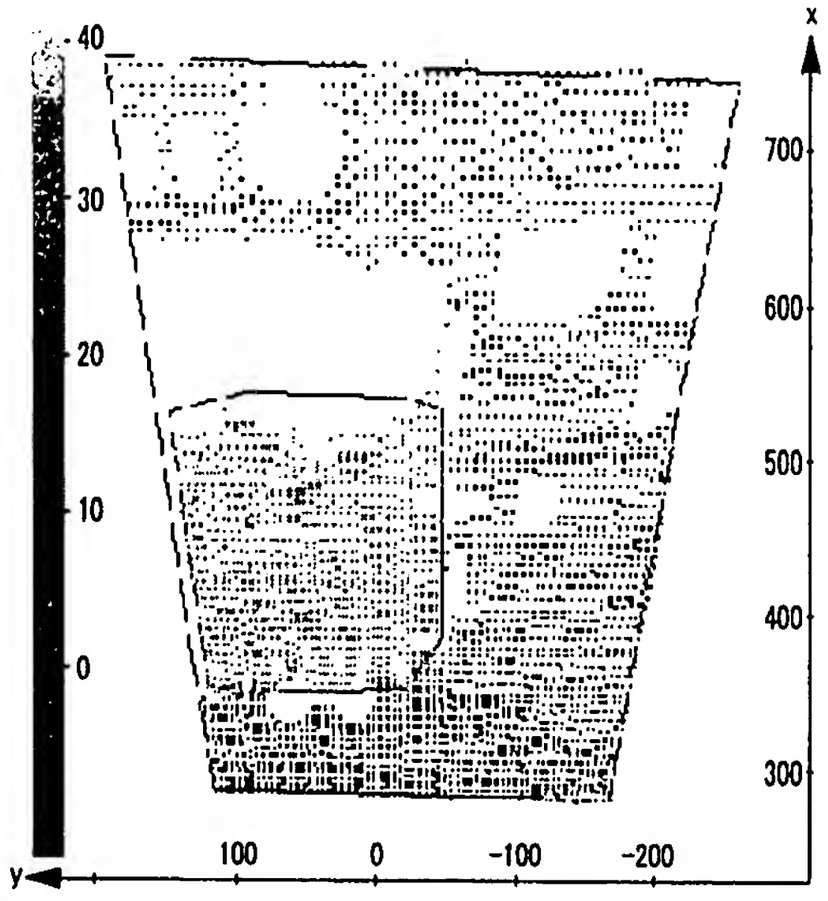


FIG.31C

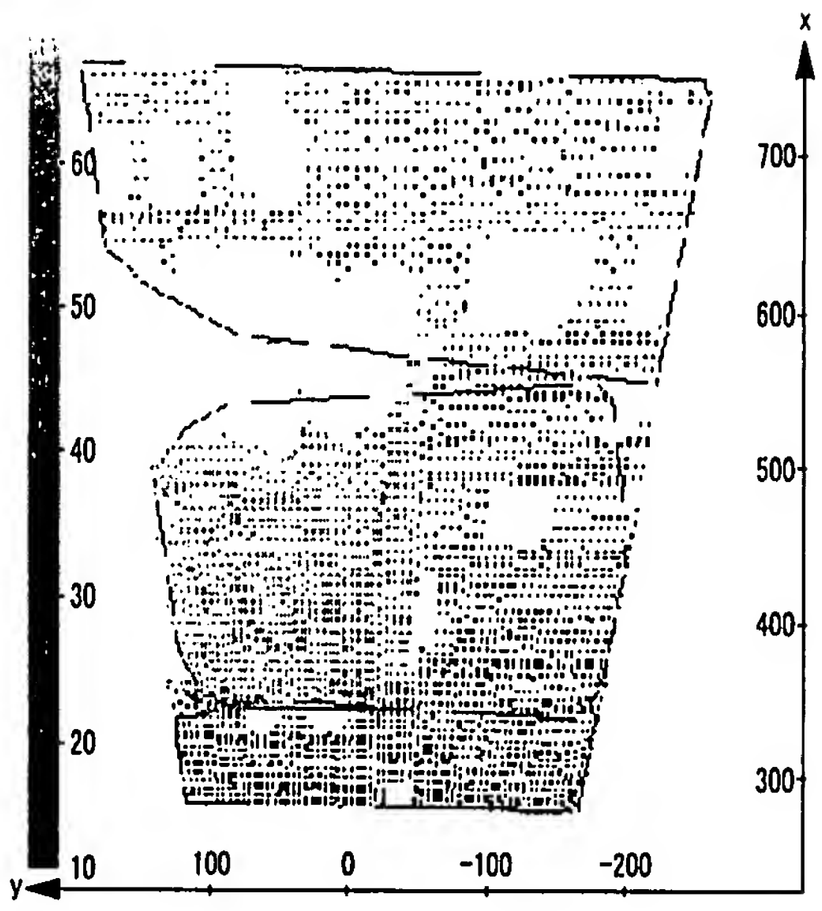


FIG.31D

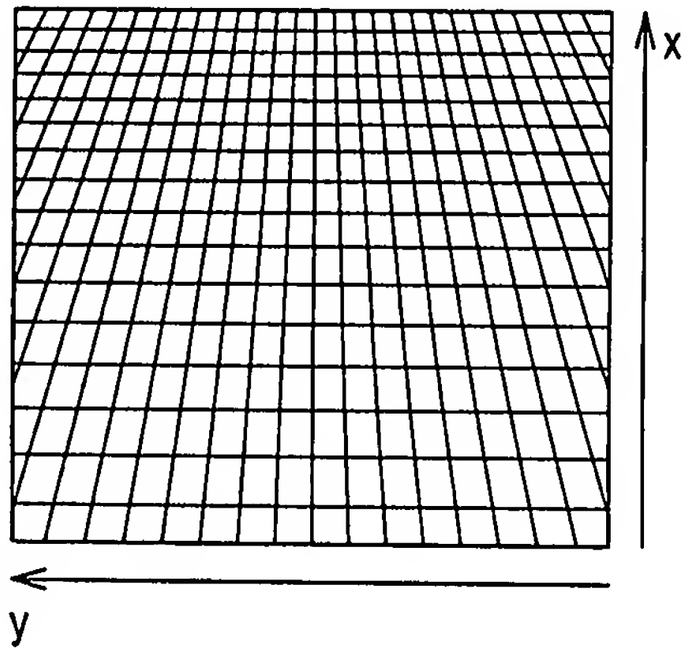


FIG.32A

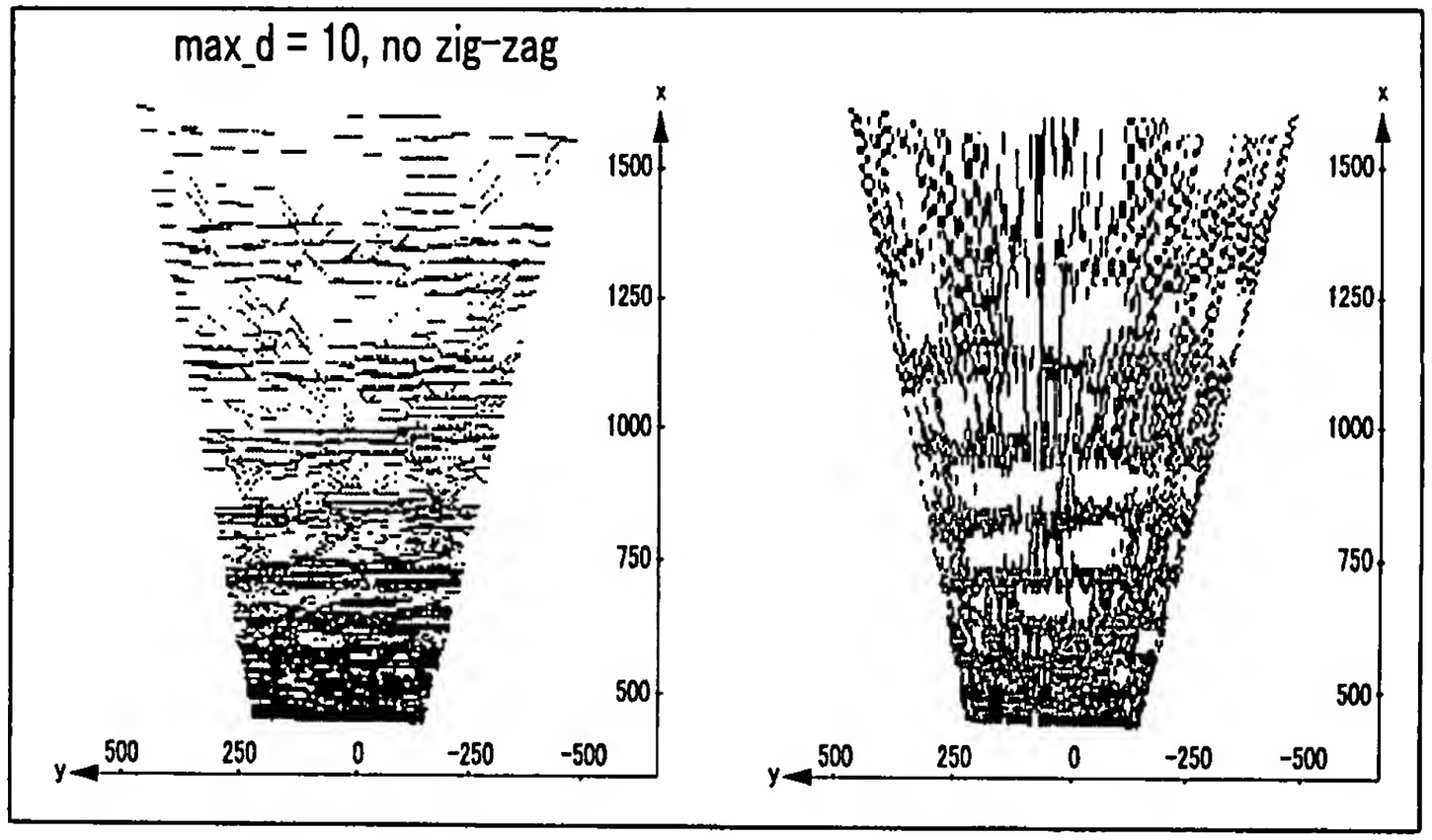


FIG.32B

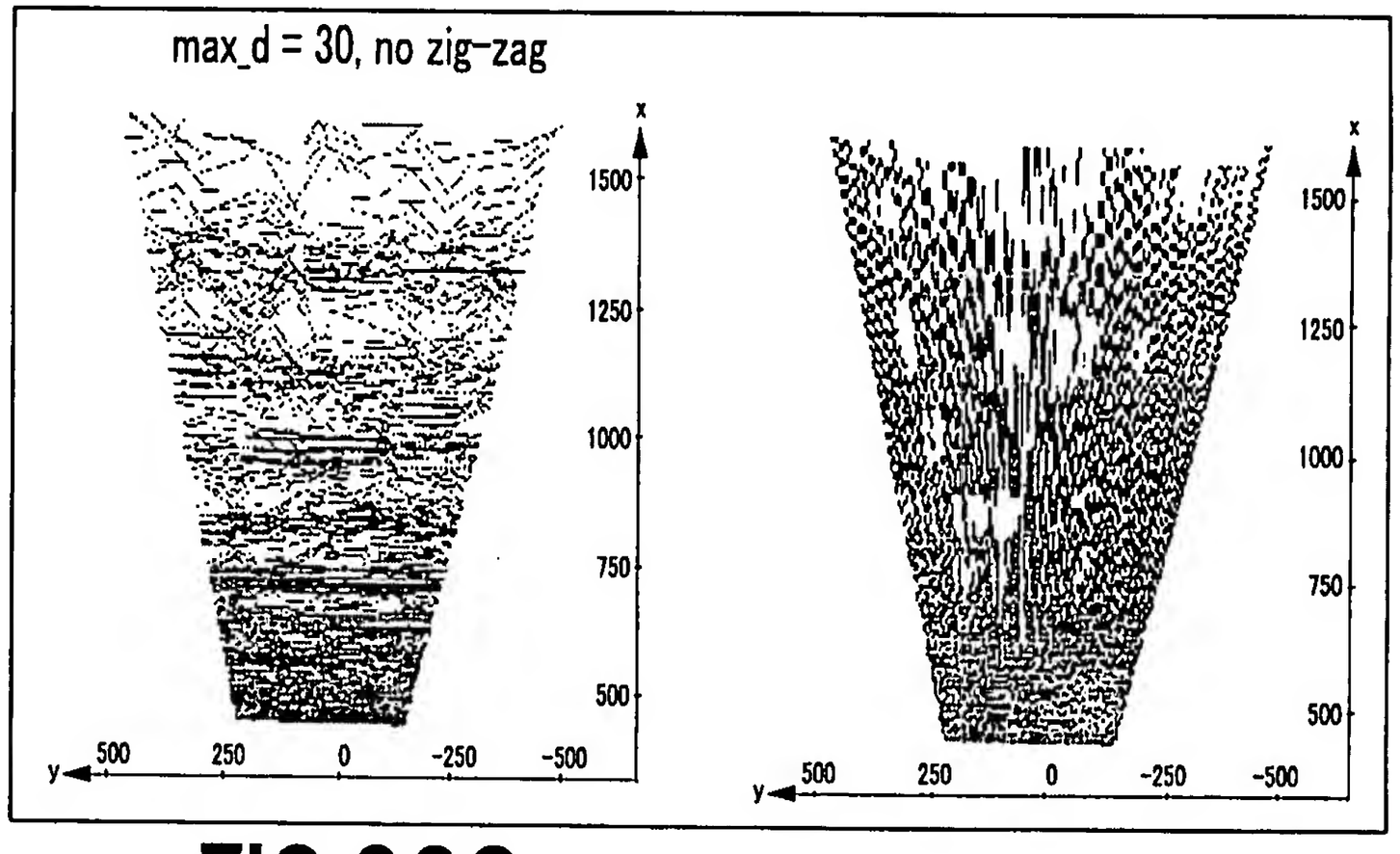


FIG.32C

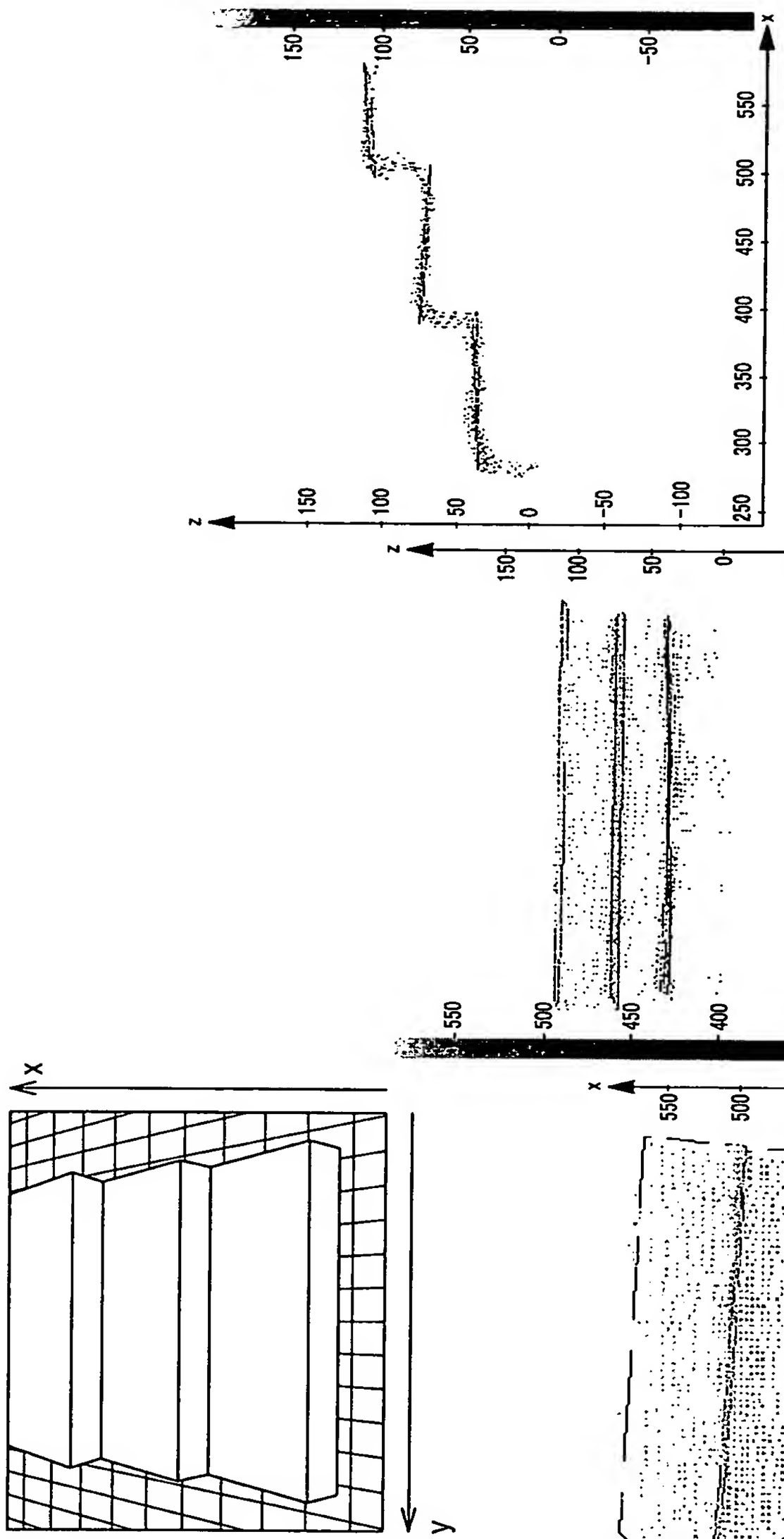


FIG.33A

FIG.33B

FIG.33C

FIG.33D

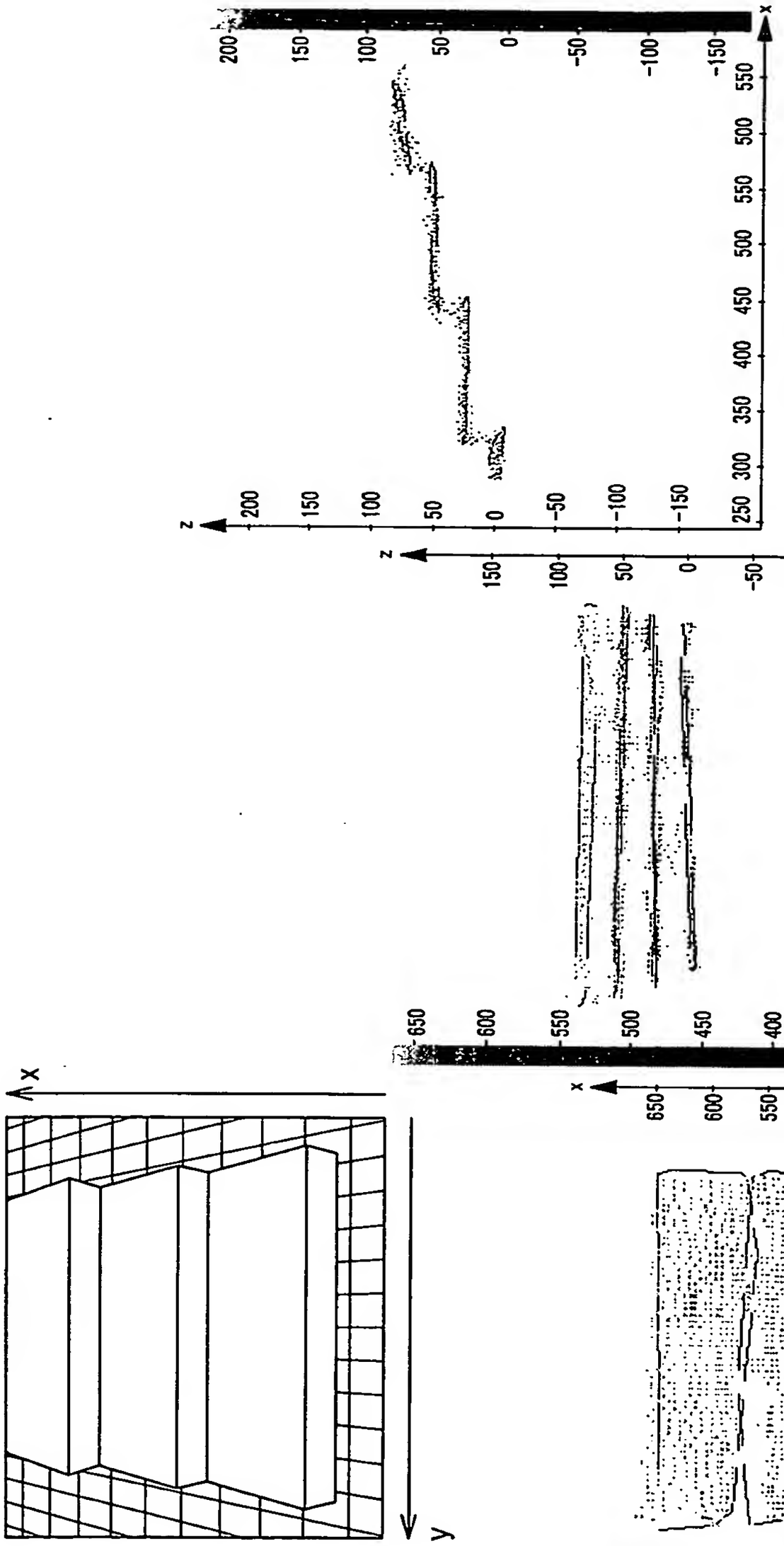


FIG.34A

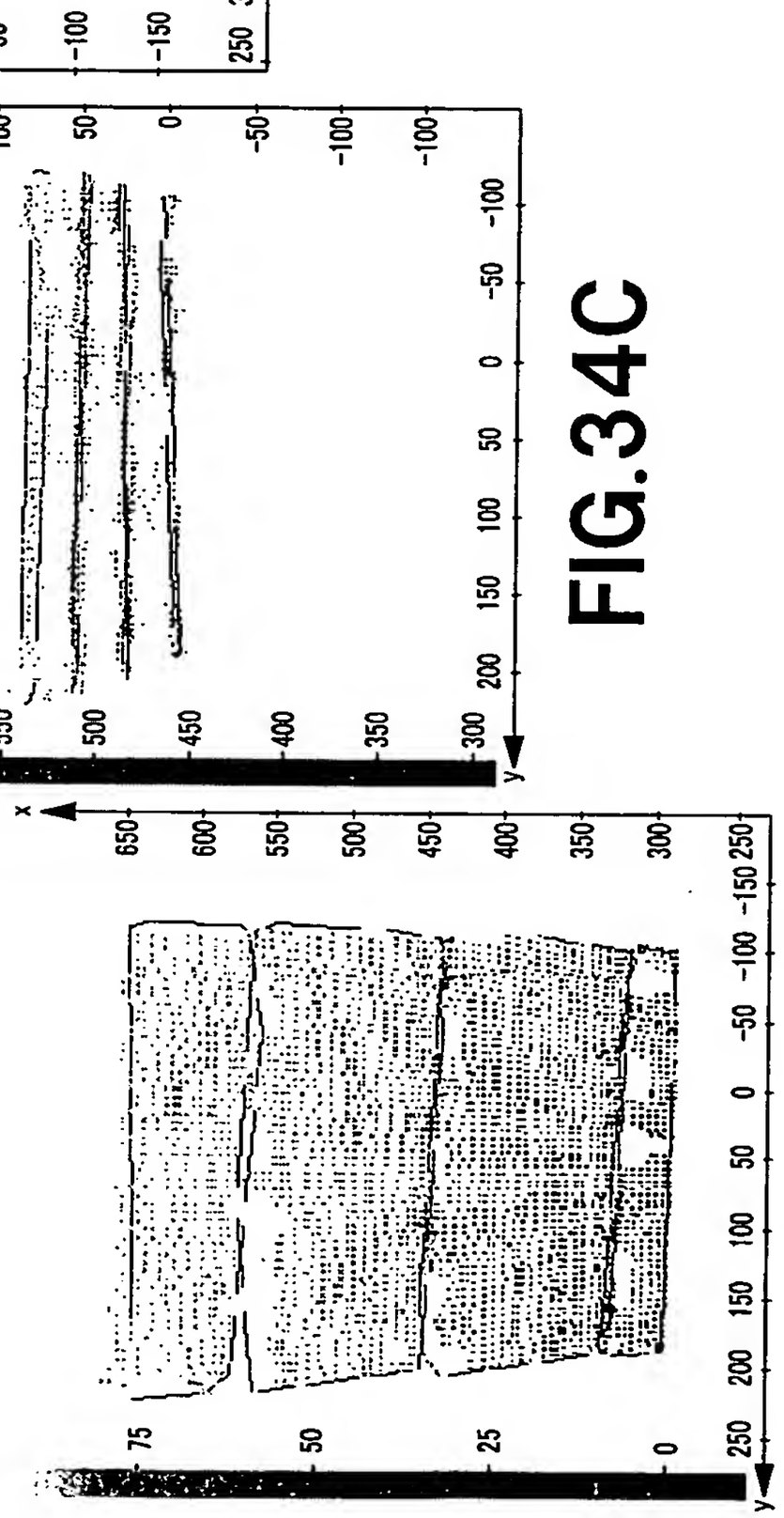


FIG.34B

FIG.34C

FIG.34D

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